22 April 2005

MILITARY OPERATIONS RESEARCH SOCIETY

MORS Workshop
How Cognitive and Behavioral Factors Influence Command and Control

28-30 October 2003
The Institute for Defense Analyses
Alexandria, Virginia

Chair: Dr. Priscilla A. Glasow, FS

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Table of Contents

Introduction

This workshop examined how cognitive and behavioral factors influence Command and Control (C2). This theme was a continuation of previous MORS fora that considered a broader, more interdisciplinary perspective of operations research analysis and its practice within the Department of Defense (DoD). It was intended that this workshop be the first in a series of MORS special meetings focused on cognitive, behavioral, and social factors. As such, the focus of this workshop was primarily on discovery and discussion, rather than the generation of recommendations. An effort was made, however, to identify some early ideas that might serve as starting points for subsequent workshops and future recommendations.

Background

The traditional view of command and control in the Department of Defense (DoD) tends to focus on the technologies used to support these functions. This perspective generally views technology as rational, beneficial, and progressive. Unfortunately, this pro-technology bias may not allow us to fully consider the effects of other systemic forces, and may limit our candid assessment of new technologies.

An alternative perspective examines the influences and interactions among the following: (1) the organization structure; (2) its people; (3) tasks; and, (4) technology. Figure 1 illustrates Leavitt's Diamond, which is taken from the organizational behavior literature of 1965. In this diagram, each of these factors is perceived as an integral and ***equally important*** element in the system. Technology is no longer the central focus, but one of several factors that must be considered.

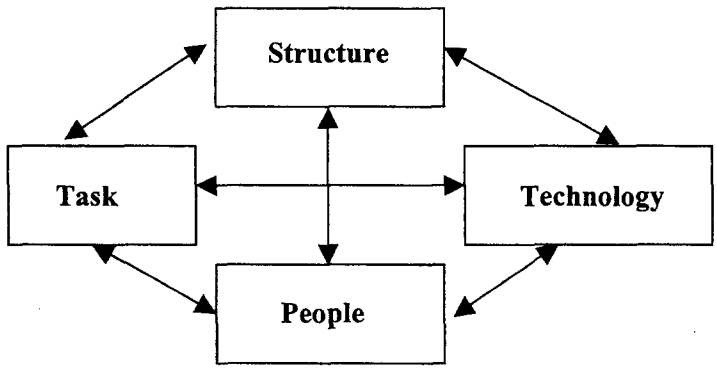


Figure 1. Leavitt, H. J. (1965). Allied organizational change in industry: Structural, technological and humanistic approaches. In J. G. March (Ed.), Handbook of Organizations (pp. 1144-1170). Chicago: Rand McNally.

This special meeting employed the alternative perspective illustrated by Leavitt's Diamond to examine the influences and interactions of people — specifically human factors — on command and control structures, tasks, processes, and technologies. Cognitive and behavioral factors were the specific human factors addressed by this special meeting. Cognitive factors refer to how people think, and include how a person relates to the environment, acquires information, and makes decisions. Behavioral factors refer to how people act, and are based on a person's beliefs, attitudes, and intentions. The participants elected to add social factors to the workshop focus to more fully represent the relevant social sciences.

Target Audience

"We are poor practitioners indeed if we cannot try to better understand the concepts and methods of other professions and seek to integrate that which adds value to our own practice."

Although operations research was originally intended to be an interdisciplinary field, it has largely evolved to address the physical sciences. Hence, the audience for the meeting was specifically broadened to include senior decision makers, warfighters, social scientists, and operations research analysts. Social scientists played a key role in guiding the other participants to a better understanding of the subject area and its challenges.

Over 80 US and international participants attended. All of the Military Services, the Joint Staff, and the Office of the Secretary of Defense (OSD) were represented, as well as several Federally Funded Research and Development Centers (FFRDCs) and a broad cross-section of industry and academia.

Format

The special meeting was presented as a mini-symposium for the general audience, followed by a workshop for selected participants. Presentations were limited to the mini-symposium so that working group sessions could be devoted entirely to discovery, discussion, and product development.

Mini-Symposium

Objectives

The mini-symposium provided a forum for developing an increased awareness and appreciation of cognitive, behavioral, and social science factors within the military operations research analysis community. The Synthesis Group developed Figure 2 to illustrate how the social sciences fit within DoD and the military operations research community.

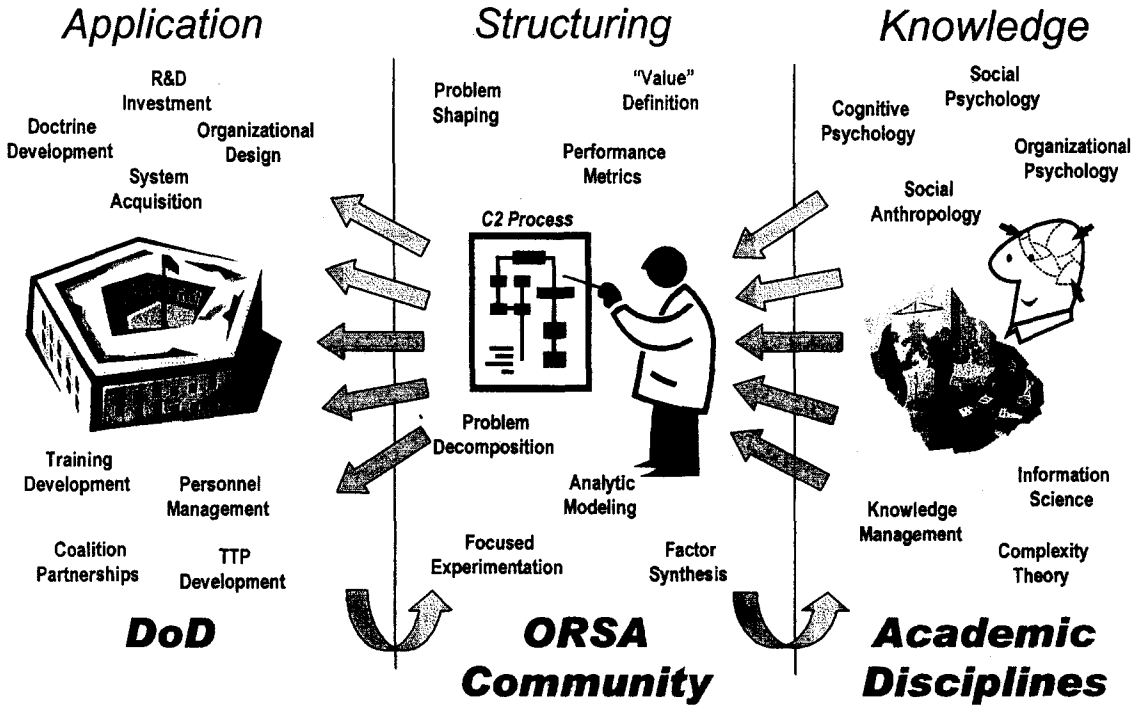


Figure 2. The bridging function of the operations research analysis community.

Starting on the right side of the chart, we know that there are many academic disciplines and bodies of knowledge that can contribute to our understanding of command and control. Among these are physiology, psychology, ergonomics, decision theory, sociology, organizational theory, and management science.

On the left side of the chart, we can identify areas within DoD that could benefit from the application of these disciplines. What is lacking is an effective bridge between these two communities.

The operations research community is ideally suited to provide that bridge. It has the ability to structure knowledge in meaningful ways to guide intelligent policy formulation, investment planning, and force development within DoD. Identifying what is important to consider in this structuring, what methods and tools are required, and what types of analytic paradigms are useful in developing this structure were all questions that were at the heart of this special meeting.

Agenda and Structure

On the first day of the special meeting, the participants were welcomed by the MORS President, the Facility Host, and the MORS Army Sponsor. The Workshop Chair also welcomed the mini-symposium participants and provided a short introduction and overview of the subject area. This overview included a summary of the workshop's objectives, the agenda, and leading issues pertaining to the workshop topic. Following the Workshop Chair's comments, a plenary session was held, followed by tutorials, and several mini-symposium presentations.

Speakers

The plenary challenge was presented by Mr. Walt Hollis, FS, Deputy Undersecretary of the Army for Operations Research. Mr. Hollis noted that we have learned to model and automate simple control tasks, but now realize that higher-level command operations are much more complex. He further stated that the benefits of automation are not fully realized until command and control processes are reengineered to allow decision makers to operate in new ways. Mr. Hollis concluded that, while much of command and control decision making remains an art and not a science, we need to better understand and reflect these processes in our analyses and models.

Although the Synthesis Group's report summarizes the presentations of the mini-symposium speakers and tutorials, two speakers had a distinct impact on the workshop portion of the special meeting. The first of these speakers was Dr. Paul Funk, LTG, USA (Ret) who provided us with an Operation Desert Storm commander's perspective. The other referenced speaker was Col Phil Exner, USMC, who led the Marine Corps' Enduring Freedom Combat Assessment Team in Iraq. Many "pearls of wisdom" were extracted from these presentations that were later widely cited during the workshop and are used here as a common foundation for this report. These pearls have been grouped according to Leavitt's Diamond diagram. They are not prescriptive ideals, but descriptive realities, that need to be addressed by our command and control structures, tasks, processes, and technologies.

Technology Pearls of Wisdom

The common theme of these pearls is simply that technology may not always be the answer and indeed, may cause other problems or set up obstacles that impede mission performance.

- Technology can work well, but still not contribute to battlefield performance
- Email, phone, and chat proliferate workload irrespective of the chain of command
- Increased capability may decrease effectiveness (more technology, information overload)
- Concern that in network-centric warfare, everything depends on the network — What if it doesn't work?
- The importance of bandwidth in Operation Iraqi Freedom (OIF)
  - Bandwidth was allocated to the higher echelons, primarily for political and strategic VTCs
  - Lower echelons didn't use technology — knew bandwidth wasn't available for operational and tactical needs
  - Lower echelons resorted to low tech methods and systems
  - Particularly problematic for ground forces where individual soldiers needed access
  - Failure to appreciate or quantify the cost of misallocating bandwidth to those who didn't need it for operational use
  - Bandwidth is a resource that we must consciously plan and manage

People Pearls of Wisdom

Dr. Funk and Col Exner also provided excellent insights about the importance of people in command and control, and their relationship to technology.

- We can no longer expect to "bend" people to technology; rather, we need to study how best to produce creativity at the nexus of people and technology
- The soldier's acceptance of new concepts and systems is essential to success
  - We need to build confidence in new ideas, and provide equipment and training that meets the soldier's needs
  - Needs are not always task related
  - Needs may be cognitive, behavioral, or social, such as how information is displayed, how teams operate, how tasks are shared
- People must have trust in their equipment and receive training to use that equipment effectively
- We must recognize the importance of relationships
  - Commanders who come up the career ladder together often form personal friendships
  - When command and control systems fail, such relationships often take over
- Technical solutions cannot replace human judgment

Task Pearls of Wisdom

Col Exner addressed the task element by focusing on decision making tasks. In contrast, Dr. Funk considered how tasks might not be performed in a timely manner where the commander requires quantifiable information, more information, or better information. Although both speakers noted the usefulness of qualitative methods, such as observation, interviews, and problem structuring, the operations research community has not yet recognized the value of incorporating these types of methods in our analyst's toolkit.

- Decision making tasks
  - How much information is enough to make a decision?
  - The lower the tolerance for risk, the higher the demand for information to avoid that risk
  - Commanders manage information differently, therefore, information must be shaped for the individual commander
- Tasks do not always require quantifiable information
- Just because something cannot be measured or quantified, doesn't mean it isn't important
  - Qualitative methods, such as observation, have their uses as well
- Commanders must perform their tasks in a timely manner
  - Concern that they will wait for more or better information rather than act or make a decision
  - Need to balance the need for quick decision making with informed decision making

Structure Pearls of Wisdom

Finally, Col Exner addressed how the organization structure may affect performance by examining the role of teams and how their formation in highly centralized organizations can adversely affect mission performance.

- The importance of teams
  - Increased centralization reduces the ability of informal relationships to influence the process
  - Centralization requires the formation of new teams that have no prior history or experience working together
  - Lack of team experience requires rules and procedures that slow the process
  - Slower process does not meet OPTEMPO requirements
- Command and control becomes synched to a sequential, procedural planning mindset rather than the dynamic rhythm of the battlefield

Workshop

Objectives

The workshop provided a forum for developing a common ground of understanding among the participants, regarding the influence of cognitive, behavioral, and social factors on the design, implementation, and performance of command and control structures, tasks, processes, and technologies.

Format

The participants were divided into four working groups that addressed specific topic areas. Over the next two days, these groups engaged in open debate and developed various insights related to the objectives of this special meeting. Each of the working groups developed a final briefing that highlighted specific insights from their discussions. The Synthesis Group integrated these insights and developed a separate synthesis outbrief.

Agenda

Workshop – Days 1 and 2

The workshop began mid-afternoon on the first day. The workshop participants broke into their working groups to focus on their assigned discussion questions. A member of the Synthesis Group was assigned to each Working Group to facilitate idea flow across the working groups.

The working groups continued to meet in session during the second day. On the afternoon of the second day, each Working Group presented an interim summary of their key discussion points, issues, conclusions, and recommendations to the entire workshop.

Workshop - Day 3

The working groups re-formed on the morning of the third day to refine and modify their ideas in light of the interim outbriefs of the other working groups. Each Working Group presented a final outbrief on the afternoon of the third day. This session concluded with a short summary by the Synthesis Group of the common issues, concerns, and recommendations identified by the workshop participants.

Day 4 morning

The Working Group Co-Chairs met with the Synthesis Group on the morning of the fourth day to finalize the draft of the Synthesis Group outbrief.

Structure

Each Working Group was led by two Co-Chairs and a Recorder. The Working Group Co-Chairs were responsible for organizing and leading the working group. They moderated the discussions and were required to participate in the workshop synthesis session on the morning of the fourth day. Working Group Co-Chairs were encouraged to recruit specific individuals to be part of their working group to ensure that the requisite expertise existed in the group.

Working Group Recorders were responsible for recording the discussion of their respective working groups, noting particularly the lessons learned, issues, concerns, and recommendations of the participants. Working Group Recorders were invited to attend the workshop synthesis session on the morning of the fourth day.

The Synthesis Group was also led by two Co-Chairs and a Recorder. All members of the Synthesis Group were responsible for participating in the workshop synthesis session on the morning of the fourth day. The Synthesis Group Co-Chairs and Synthesis Group Recorder were also made aware of the meeting schedule and report deadline. Each was asked to acknowledge that he or she would be able to support these requirements as a condition of serving in a workshop leadership position. In the event that a Synthesis Group Co-Chair or Synthesis Group Recorder was unable to fulfill his or her duties, that individual was expected to help the Workshop Chair identify a suitable and available substitute.

Working Group Leaders

The following participants served as co-chairs and recorders of their respective groups:

Working Group 1
- Co-Chair: Dr. Alan Zimm, JHUAPL
- Co-Chair: LT Alex Hoover, COMOPTEVFOR
- Recorder: Mr. Brian Widdowson, MITRE

Working Group 2
- Co-Chair: Dr. Kim Holloman, EBR
- Co-Chair: Mr. Dave Garvey, Alidade, Inc.
- Recorder: Ms. Tina Brown, MITRE

Working Group 3
- Co-Chair: LT Katie Shobe, USN, NSMRL
- Co-Chair: Dr. Barbara Black, ARI
- Recorder: Mr. Dan McConnell, MITRE

Working Group 4
- Co-Chair: Dr. Lyn Canham, AFOTEC
- Co-Chair: Dr. Gwen Campbell, NAVAIR
- Recorder: 1stLt Lindsey Schmidt, USAF, AFOTEC

Synthesis Group
- Co-Chair: Dr. Dennis Leedom, EBR
- Co-Chair: Dr. Lynee Murray, NUWC Newport
- Recorder: Ms. Sharon Nichols, AFSAA

Working Group Topics

The following discussion questions were assigned to the four working groups:

Working Group 1 - Factors

WG 1.1 - What cognitive and behavioral factors are currently recognized in command and control?

WG 1.2 - How are these factors incorporated in command and control structures, tasks, processes, and technologies?

WG 1.3 - How well do current models reflect these factors and their various influences on command and control?

Working Group 2 – Future

WG 2.1 - When planning for future command and control systems, how should system requirements be written to include the effects of cognitive and behavioral factors on command and control processes?

WG 2.2 - What are some of the ramifications of cognitive and behavioral factors on future command and control systems?

Working Group 3 - Implementation

WG 3.1 - Given that social scientists have knowledge about the potential impact of a given cognitive or behavioral factor, how can this knowledge be implemented in command and control processes, technologies, and training?

WG 3.2 - What barriers currently exist in implementing such knowledge? What impact do time and resource constraints have on our ability to consider and include cognitive and behavioral factors? Are these barriers the result of gaps in research and development? How can those barriers be overcome?

Working Group 4 - Methods

WG 4.1 - Identify methods that can be used to study and measure the influence of cognitive and behavioral factors on command and control structures, tasks, processes, and technologies.

WG 4.2 - What is the status of current methods? What are the attributes and limitations of those methods?

Synthesis Group

Provide a mechanism to ensure cross-fertilization of ideas among the working groups, and to integrate and synthesize ideas from the workshop.

Members of the Synthesis Group will participate in the Working Groups as a means of facilitating conceptual synthesis and integration.

Findings

The following findings draw heavily from the Synthesis Group's outbrief, but also highlight some of the key findings of the individual working groups. Rather than review the working groups' findings in numerical order, they are addressed in logical order following the content of their findings and how each working group's findings fit with those of the other working groups.

WG 1 was responsible for identifying cognitive, behavioral, and social factors that influence command and control structures, tasks, processes, and technologies. Figure 3 is based largely on that work, although WG 4 also identified many of these same factors in having potentially significant impacts on mission outcomes. Additionally, WG 2 used a similar diagram to reflect the holistic system view that they felt was important in looking toward future needs of command and control.

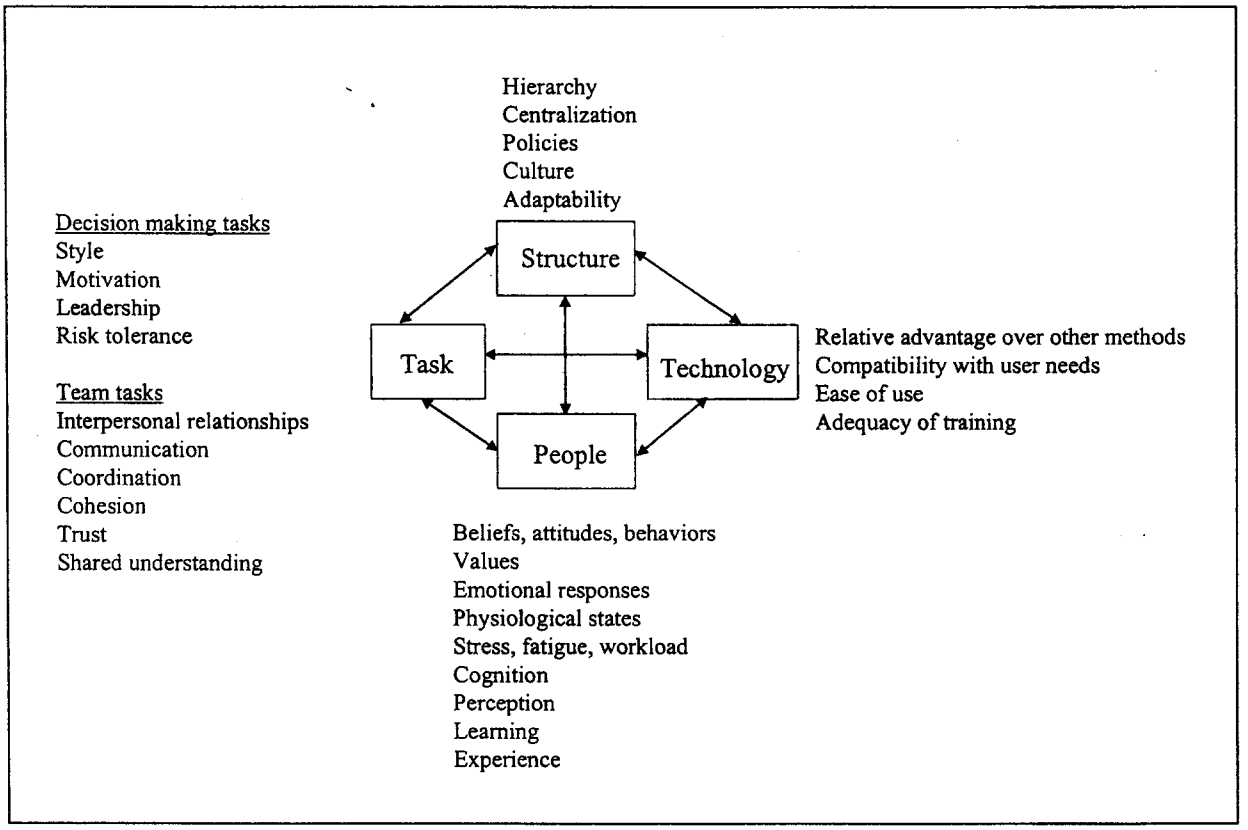


Figure 3. Cognitive, behavioral, and social factors that influence command and control.

WG 4 discussed methods for studying and measuring the influence of cognitive, behavioral, and social factors on command and control. Following are some of their observations:

- Use a convergence of multiple measures for a single construct
- Shared construct definitions are critical for metric development and measurement success
- Some measurement dimensions:
  - Objective versus Subjective
  - Process versus Outcome
  - Quantitative versus Qualitative

WG 4 also identified some of the gaps that currently exist in our method and measurement capabilities:

- There are fewer methods for studying teams and organizations than for studying individuals
- There is a need for more interdisciplinary collaboration, including that between the physical and social sciences
- Methods and metrics are needed to assess data-poor environments
- Uncertainty exists in determining which factors should be measured to obtain the most relevant insights into a problem

WG 3 developed a detailed spreadsheet (Figure 4) that examined the problems posed to cognition, behavior, and command style by such processes as information gathering, decision making, communicating, providing feedback, technology, and training.

Problem	C2 process 1	C2 process 2	C2 process 3	C2 process 4		
	Info Gathering	Decn Making	Communicating	Feedback/NCW	C2 Technology	C2 Training
Cognitive Factors (Behavior/Aspects)	1) data overload	1) groupthink 2) (decision paralysis)	1) bottlencks 2) unanalyzed data	1) real time filtering	1) lack of objectives for system development 2) Bandwidth 3) no standards for non-ergonomic cognitive factors for systems design	1) how to recreate a thinking enemy
Human Performance (Behavior; indiv or team)	1) fatigue/physio stress 2) signal detection & classification	1) fatigue/physio stress adverse effects are exacerbated 2) allowing for creativity while adhering to standards	1) language barriers 2) cohort issue 3) service culture	1) digital systems - alerts/shared knowledge 2) analog systems -manual processing 3) COA analysis & wargaming	1) need to accommodate individual differences	1) how to create a physiologically realistic friendly/ enemy situation
Command Style (interpersonal behavior)	1) striking the balance of staff autonomy and cmd directed necessity 2) varying levels of micromanagement involved for subordinate action	1) striking the balance between consistency (standards) of decisions with creativity and initiative 2) influence of negative command climate	1) degradation of VTCcapability 2) balance in battle preparation and comms to accommodate robust plan adjustments	1) identifying causal results attributing cognitive factors 2) capturing the logic/reasoning involved with actual decisions	1) automating capture of tagged data to subjective data 2) design specificity between staff and command requirements	1) how to compensate for absence of experienced commander 2) training criteria to estabhish effective command styles 3) need to represent asymmetric/foreign command styles

Figure 4. Typical problems posed to cognition, behavior, and command style by command and control structures, tasks, processes, and technologies.

For example, information gathering can cause data overload at a cognitive level, fatigue and physiological stress at a human behavior level, and invoke problems associated with micromanagement in terms of command style.

WG 3 then developed a second spreadsheet (Figure 5) that examined the implementation of cognitive, behavioral, and command style actions to mitigate these problems.

For example, to alleviate the problem of data overload, WG 3 recommended that the relevance of incoming data be assessed to filter or aggregate data and avoid cognitive overload. Similarly, data collection priorities could be established through staff interactions to preclude fatigue and physiological stress. Finally, experimentation with different situational styles could provide alternative responses at the command level to avoid micromanagement.

Implementation	C2 process 1	C2 process 2	C2 process 3	C2 process 4		
	Info Gathering	Decn Making	Communicating	Feedback/NCW	C2 Technology	C2 Training
Cognitive Factors (Behavior/Aspects)	1) relevance 2) filters 3) data aggregation	1) exercises 2) trained facilitators 3) mentors	1) training in relevant service/coalition language and cultura differences	1) processes to check for receipt/ misunderstanding critical orders	1) include cognitive scientists in all phases of acquisition 2) use of portal technology 3) visualization technologies	1) include cognitive scientists in IPTs 2) develop performance standards
Human Performance (Behavior; indiv or team)	1) using staff interactions to determine collection prioirities 2) integrating performance degradation studies with doctrine		1) consolidate or centralize effort to research/ understanding implications of Reachback in various types of employment, e.g. UAV, vehicle maintenance, medical consultation, etc.	1) Joint training 2) end of NCW training exercise should assure HEMP destroys all electronics - continue to fight without NCW	1) modularity and tailorability solutions 2) early use "human in the loop" simulation in design and development, e.g.SIL (systems integration labs)	1) need for training SIL 2) integrating performance degradation results into simulations/other training models 3) end of every NCW training exercise should assure HEMP destroys all electronics - continue to fight without NCW 4) training differences between more modular force structure and unit replacement policy
Command Style (interpersonal behavior)	1) experimenting with situational styles to dermine guides for particular situations 2) staff training for different echelons	1) In training focus on creativity aspects of DM and capture data relating to environmental factors	1) experiment with differing Cmd styles during controlled info gaps and battle prep	1) allow cognitive scientists to participate in various operations to record selected metrics 2) gain closer access to Cmdrs pre/post activity	1) incorporate techn expertise into decision making process	1) ensure in individual, collective sequencing of training, it includes new or alternative technology approaches /capabilities 2) C2 training in command style and cultural awareness

WG 3 also explored some of the barriers that hamper knowledge sharing about cognitive, behavioral, and social factors.

First, they noted that socio-cultural differences among the Services contribute to significantly different views of command and control, which further lead to different views of cognitive, behavioral and social components of command and control.

Second, WG 3 observed that it is widely accepted in DoD that the future will involve a wide spectrum of military operations, involving coalition partners and large numbers of non-military organizations. It is necessary that any program dealing with the cognitive, behavioral, and social components of command and control recognize and incorporate these complexities.

WG 3 also addressed the apparent accepted adequacy of legacy systems. Specifically, DoD has already fielded many command and control programs without adequate consideration of cognitive, behavioral and social factors. While there is considerable concern about the lack of recognition of those factors, DoD has otherwise seemed satisfied with its accomplishments to date. The apparent adequacy of present and planned command and control programs will be difficult to argue against. Analyses are needed to demonstrate the benefits of incorporating cognitive, behavioral, and social factors in the design of command and control systems.

Finally, WG 3 noted that introducing cognitive, behavioral, and social factors in the design, development, test, acquisition, and deployment of command and control systems is a complex process that will require ingenuity, perseverance, and considerable high-level support in the DoD.

WG 2 examined the ramifications of cognitive, behavioral, and social factors on future command and control systems. Figure 6 resulted from their deliberations and those of the Synthesis Group in identifying the key drivers and resulting requirements for future command and control systems.

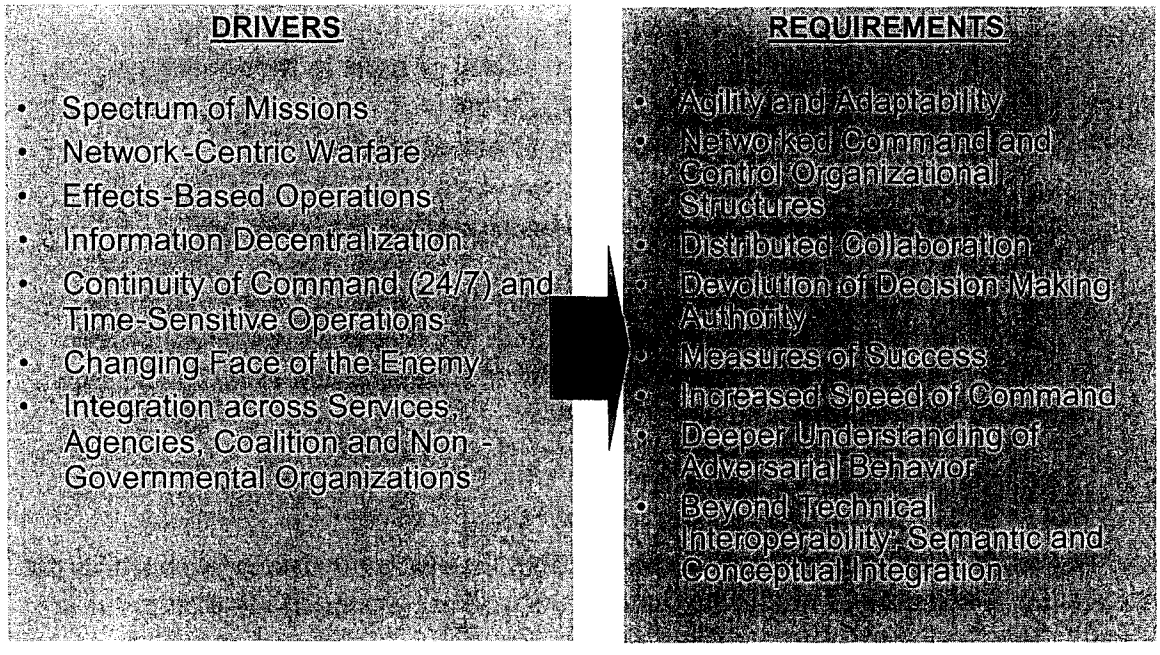


Figure 6. Key drivers and requirements for the future.

The left hand box shows the set of drivers that suggest the nature of future military operations. In turn, these drivers call for certain cognitive, behavioral, and social requirements that are expected to characterize future missions. It is important to think of the requirements in terms of what they mean to the *human* component, rather than in terms of the mission, task, or technology. For example, agility and adaptability refers to the human, rather than the command and control process. Similarly, distributed collaboration refers to the people who collaborate, rather than the tools used to collaborate.

The Synthesis Group noted that we must understand, model, measure, and develop human enabling factors that are necessary to fulfill the requirements listed in Figure 6. Some key enablers generated by WG 2 are listed on the left-hand side of Figure 7.

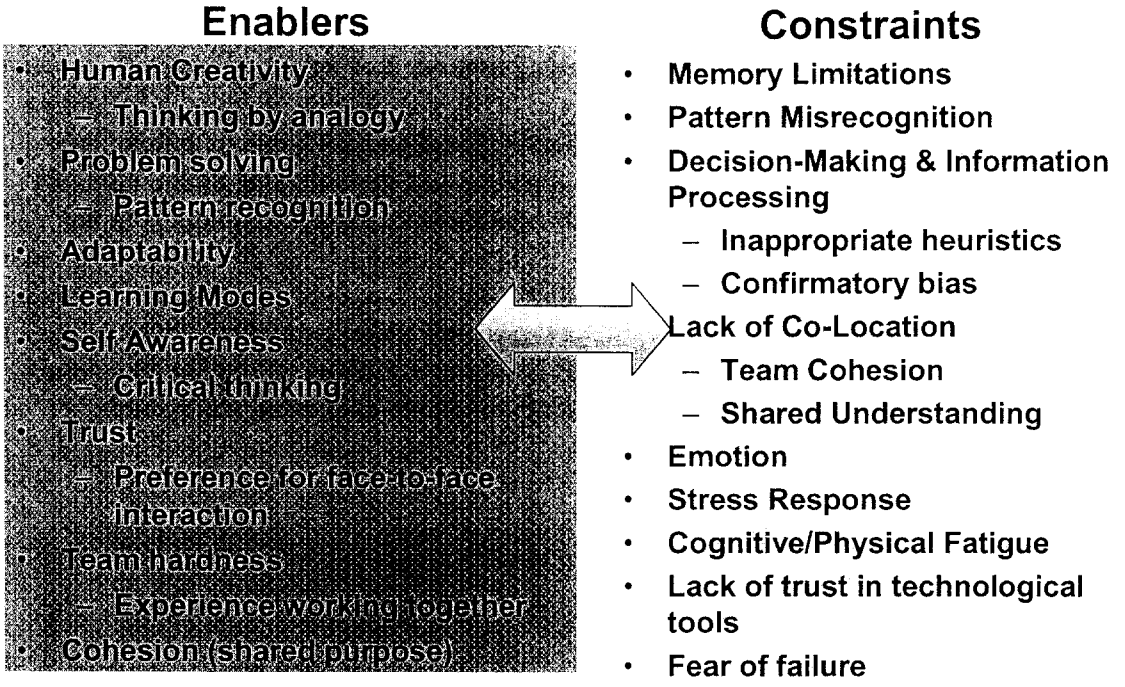


Figure 7. Key cognitive, behavioral, and social enablers and constraints

However, we must also recognize the inherent constraints that the human bring to the table, some of which are listed in the right hand box of Figure 7. Both enablers and constraints must be accounted for in the conceptualization and design of future command and control structures, tasks, processes, and technologies.

Recommendations

The following set of recommendations was derived from the pearls of wisdom provided by the mini-symposium speakers and from the products of the working groups and Synthesis Group. Again, they follow the format illustrated by Leavitt's Diamond.

Technology

- We need to better assess the direct contributions of new technologies on battlefield performance through studies and analyses during system acquisition and initial fielding. Those technologies that adversely affect battlefield performance should be refined or removed.
- We need to conduct information overload studies that examine the impact of multiple, competing media (email, phone, chat, etc.) on individual and team workload and

effectiveness. Changes should be made to doctrine and organization structures to employ only those media that have a positive impact on individual and team workload and effectiveness.

- Research is needed to identify network dependencies and to determine the optimal mix of uses for limited bandwidth and other network assets. System or structure redundancies should be available to mitigate potential network failures. Alternative lines of communication and collaboration should be identified in the event that the network fails.

People

- We need to identify the cognitive, behavioral, and social needs of individuals and teams, as they relate to command and control structures, tasks, processes, and technologies.
- User acceptance studies of new structures, tasks, processes, and technologies should be conducted to ensure that new approaches and tools meet the cognitive, behavioral, and social needs of the users.
- We need to assess the role of trust in technology, and identify approaches for instilling confidence and trust.
- Training programs must be developed to incorporate the user's cognitive, behavioral, and social needs.
- We need to better understand the roles of informal relationships and their influences on command and control decisions and actions.

Task

- We need to conduct studies to determine how much information is enough to support decision making. What is the quantity and quality of information that is needed? How reliable do information sources have to be?
- Decision tools must be designed that shape information for the individual commander.
- We need to incorporate qualitative methods in the analyst's toolkit to enhance information gathering and assessment.

Structure

- Finally, we need to more fully examine the role of teams in command and control. How do teams fit within existing organizational structures? How are teams formed? What team roles can be identified? How is team experience and trust developed? How is workload shared within a team? What processes make teams effective? And how do teams use various technologies to their advantage?

Summary

As a result of this special meeting, a broader understanding was achieved concerning the roles that cognitive, behavioral, and social factors play in influencing command and control structures,

tasks, processes, and technologies. The alternative holistic perspective afforded by Leavitt's Diamond as an organizing concept greatly contributed to the coverage of the special meeting topic, despite its breadth and depth. Finally, the commitment to discussion and fair debate among the participants ensured that a balance of views was heard and that shared appreciation was achieved.

It is expressly hoped that this special meeting will serve as the genesis for a series of MORS meetings to address cognitive, behavioral, and social factors as they relate to command and control, and more broadly, to the practice of military operations research. Although this special meeting established a starting point for future discussions, there is much work yet to be done.

Working Group 1 – Factors Outbrief

How Cognitive and Behavioral Factors Influence Command and Control

28-30 October 2003
The Institute for Defense Analyses
Alexandria, Virginia

Participants

• Dr. Alan Zimm	
• LT Alex Hoover	OT&E
• Brian Widdowson	M&S
• Kelaine Nick	Army Modeling
• John Prince	Campaign Level Simulations
• Major Thomas Dillingham	Army Experimentation – Artillery
• Major Ben Blas	Accessing C4ISR Architecture – Armor
• Maria Stropky	System Engineering
• Capt Eunice Ciskowski	Storm Model Manager – Acquisition
• Mitzi Wertheim	Social Anthropologist
• Paul Pearce	C2 Algorithms
• Clinton Ancker	C2 Doctrine – Armored Cavalry
• Dr. Jill Drury	Evaluating Large Scale C2 Systems
• Sam Waugh	Air Operational Analysis, AI
• Dr. Arend Woering	Human Factors

For group introductions, we identified ourselves through our work and experiences instead of our organizations. We found this was very important, especially for the uniformed personnel, who would have been too easily stereotyped had we not focused on individual experiences. We had a very diverse group and were interested in both identifying the commonality across disciplines as well as preserving the unique concerns that some of the disciplines had.

Tasking

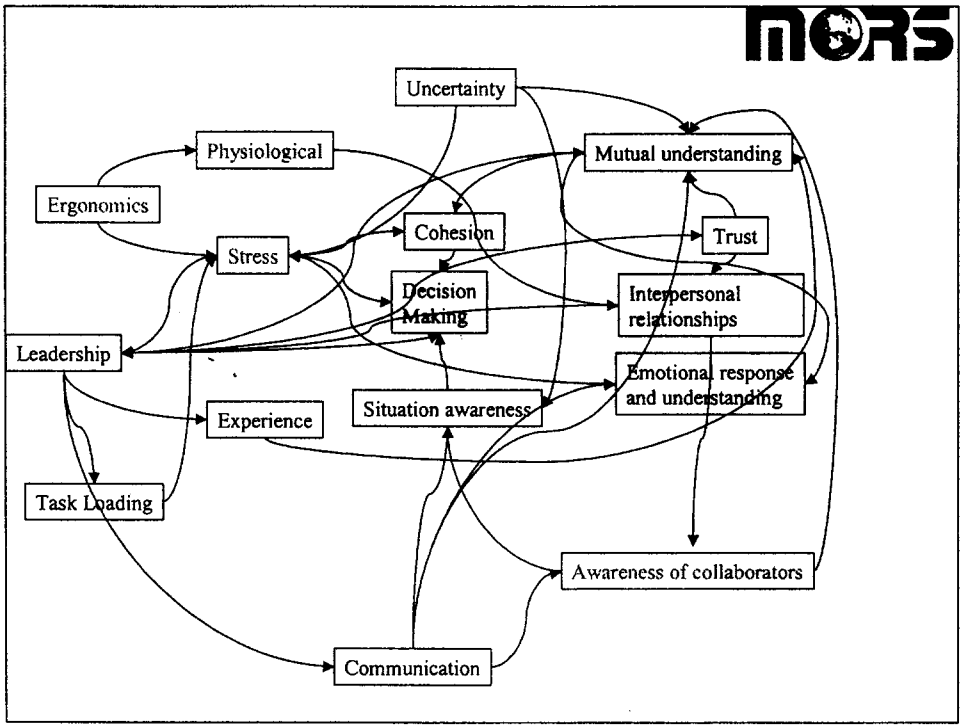
- WG 1.1 - What classes of cognitive and behavioral factors are currently recognized in command and control at the operational level of warfare?
  - Command and control is the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission
- WG 1.2 - How are these factors incorporated in command and control: structures; tasks; processes, and technologies?
- WG 1.3 - How well do current models reflect these factors and their various influences on command and control?
  - Computer Models
  - Academic Models
  - Mathematical Models
  - Conceptual Models
  - Operational Models
  - Analytic Models

The first step we took was to come to a common understanding of the tasking and scope the types of answers we would investigate.

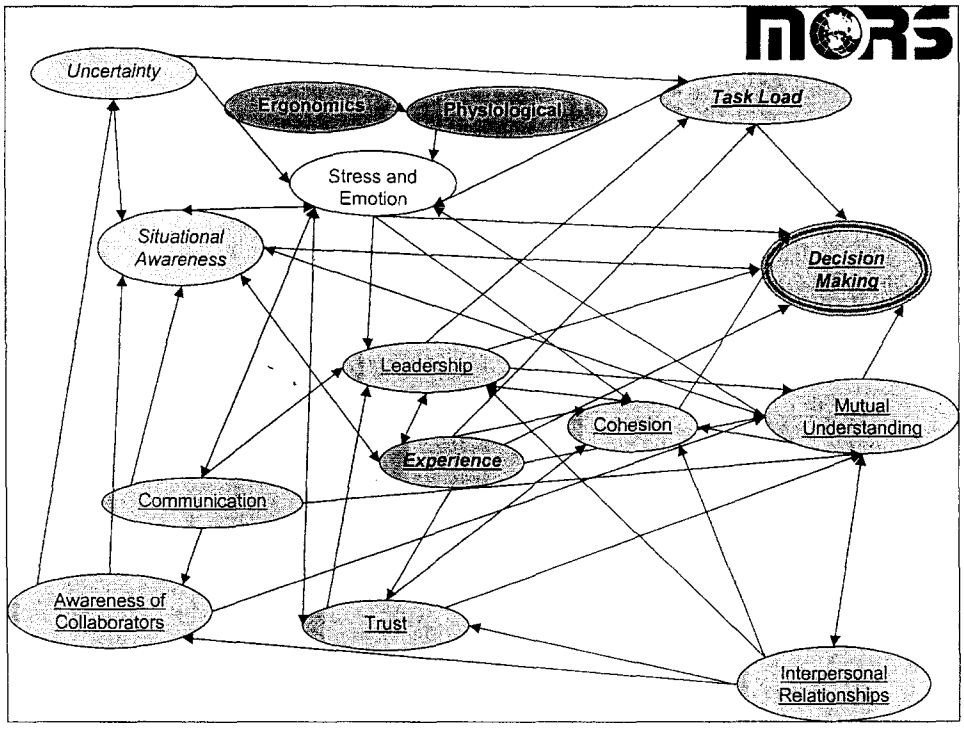
For Question 1.1, the group felt the idea of "command and control" needed to be specified. Since C2 was to be the focal point of our work, we developed a clear definition. The definition was not used to filter what would or would not be included in our discussion, but rather to organize the flow of the discussion. Only factors that directly addressed the exercise of authority and direction of forces would be considered first order factors. Other factors, when identified, would be required to be traced to the first order factors.

Question 1.2 seemed to be too broad in scope to be addressed in a workgroup. Group members felt that they would not be able to give any type of comprehensive answer, even from within their own disciplines.

Question 1.3 also seemed broad. Since this question did not directly address incorporation of cognitive factors into specific systems, the group decided to identify several categories of cognitive model to help decide how well the individual factors have been represented.



This slide is intended to be demonstrative rather than explanatory. This represents a capture of the first round of brainstorming in identifying various cognitive factors and their influences on each other.



This "simplification" of the previous slide illustrates the refinement process that the group went through in the attempt to understand the influence of the cognitive factors on the C2 process. One of the initial steps in the refinement was to classify the factors into three separate categories: Physical, individual and social. Even this step was seen to be a bit more subtle as some factors could not be so easily contained. In the diagram red, yellow and blue represent physical, individual, and social factors, respectively. Green represents the overlap of individual and social (yellow and blue) factors. Stress and emotion could not even be boxed into a double category, and is colored white to represent the tight mixing of all three "colors" of factors.

The relationships, especially the direction of the relationships, was also a point for iteration and discussion. As with the complexity discovered in categorization, the group recognized that a "complete" or "correct" answer would not be possible. However, the groups consensus was that a self-consistent model of the relationships would be achievable.

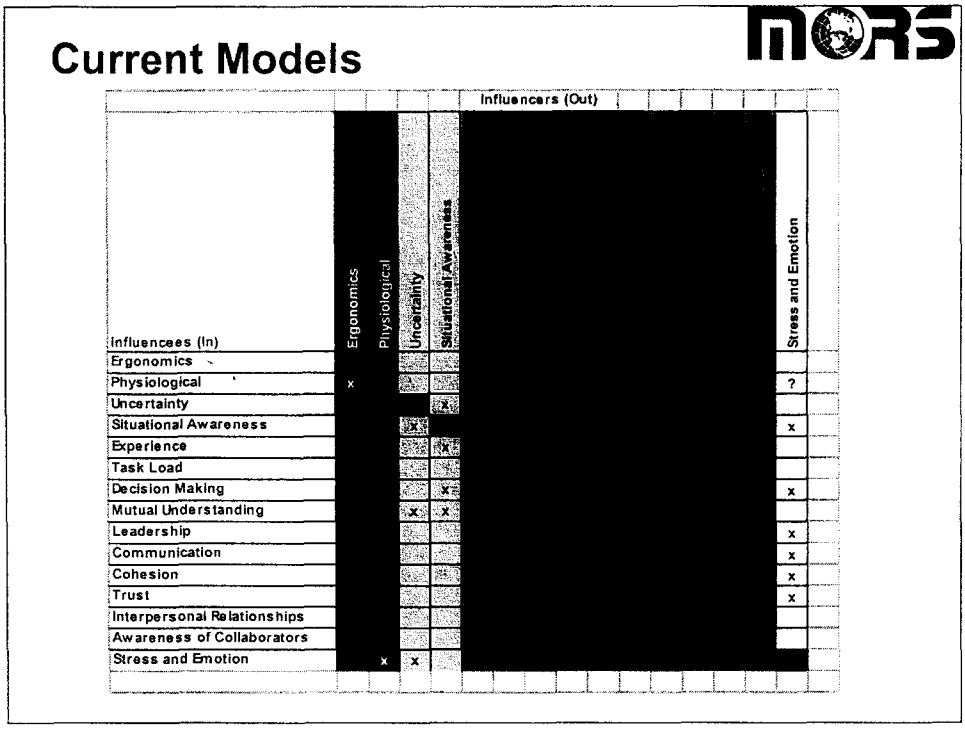
The next five slides represent the finalization of the cognitive model, which is split into two fundamental parts. The first part is a formal representation of the relationships that is intended to serve as a basis for building models of the cognitive environment and using them within C2 models to for analysis of cognitive effects. The second part is the semantic definitions of the factors themselves, which are felt to be consistent with the formal model from the standpoint of the various disciplines involved in their development, which is intended to aid in the more difficult part of modeling – understanding how to design and apply the model.

Given the definition of C2 the group used for this question, "decision making" was identified as the terminal node of the model.

Editor Note: Colors are depicted as follows:

Red – Bold *Yellow – Italics*

Blue – Underlined ***Green – Bold, Italics, Underline***



This is simply a matrix refinement of the "gozintos" and "gozouttas" of the formal part of the relationship model. Each "x" in the matrix represents a scalar influence of one factor upon another.

From the model, it is apparent that some of the factors could be mathematically subsumed by other factors. They have been left explicit in this model because of the differences in the semantic definition of the factor as provided in the next four slides.

Definitions

- Ergonomics
  - Human factors related to how the measurable size or measurable attributes (e.g. strength, endurance) affect performance
- Leadership
  - The art of applying will to others to achieve a desired byproduct or objective
- Task Load
  - The summation of the people, places, and things for which someone is responsible (as differentiated from their effect on performance) [organizations, individuals]
- Stress
  - Physiological and mental response to situation that may effect the person's performance.
  - Mental, emotional, or physical tension, strain, or stress resulting from exposure to external conditions.

The definitions of the factors are designed to allow each factor to be used as either an external influence or an internal node for the model, depending on how the model is to be used for analysis of cognitive factors.

Definitions

- Physiological
  - Factors pertaining to relevant physical and chemical responses of the human body in reaction to changes in the internal or external environment.
- Experience
  - Sum total of learned knowledge as perceived as relevant to current situations.
- Decision Making
  - The process or act of making a choice or selection.
- Cohesion
  - A state of unity to achieve a common goal.

Definitions

- Uncertainty
  - The perceived degree of error in the system state
  - Lack of information – unknown – ambiguity – uninterrupted information
- Situational Awareness
  - The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.
  - The knowledge of friendly, enemy, and operational environmental factors generated by both human and technical means derived from the COP.
- Communications
  - The activity of sharing information or data to facilitate mutual understanding, in order to create situational awareness.
- Mutual Understanding
  - A shared and unambiguous understanding of current situational awareness.

Definitions

- Trust
  - The psychological state in which one has established an acceptable degree of faith in the ability and intent of another.
- Interpersonal Relations
  - Factors derived from personality and experience, similarities and differences, that contribute to the cohesion and trust of the team.
- Emotional Response
  - An innate reaction to either an external or internal stimulus governed more by the psyche rather than the conscious reasoned state.
- Awareness of Collaborators
  - The understanding that one collaborator has about the presence, identities, and activities of the other collaborators without the first collaborator having to explicitly request the information or the other collaborators having to explicitly transmit it.

Current Models

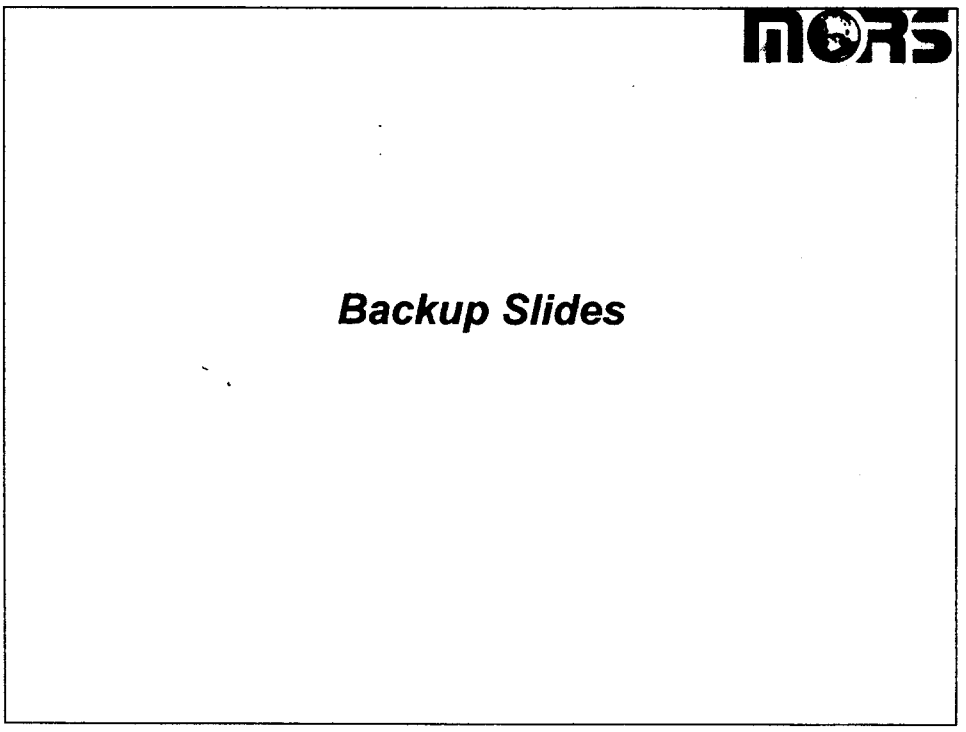
	Importance			Gap		
	Major	Midling	Minor	Too Difficult	Midling	Can Model
Ergonomics			12	0		16
Leadership	10			7		
Task Load	5	4	4			8
Stress & Emotion	10			7		
Physiological		8			6	6
Experience	8				4	5
Decision Making	Shouldn't be here to begin with				7	
Cohesion	5	6	1	9		
Uncertainty		8			9	
Situational Awareness	7			3	3	5
Communication	6	4				10
Mutual Understanding	3	3	5	5	6	
Trust	1	6	4	8	3	
Interpersonal Relationships	1	5	5	7	4	
Awareness of Collaborators	2	3	6	1	8	2

Notes: ***(Shown on the Spreadsheet as triangles in upper left hand corner of cell.)***
3B. Lack of personal knowledge of subjects and applicability to modeling
4E. Isn't important in isolation -- must be looked at holistically
4I. Agent and team models that account for leadership
6E. Not important in the time span of interest or the operational level of command
6G. Many of votes reliant more so on the emotional aspect
10E. Regarded cohesion as subsumed by others
11B. Compare ground truth w/ collected information and see how that impacts results. The gap is how it affects the decision making
13H. Good at passing physical info, but not intents/feelings.
15I. Type of model affect how important it is -- WWII vs. OOTW.
16C. Sam outlier often due to his perspective as modeler of teams.

Using the cognitive factors already identified, the group went through several rounds of discussion and voting on how important the factors were to current applications and what the gaps in current practice were. The goal was to provide guidance on how to best allocate effort in improving our ability to model cognitive factors in understanding C2 systems.

The importance votes are intended to gauge how important the factors are to the practice of analysis of C2. The gap votes are intended to describe how easily we can model and apply the models of the factor in current models. Combining the two sets of expert opinion should allow a sponsor to identify individual efforts that are consistent with their goals.

The voting results are embedded into the slide from an Excel spreadsheet. Minority ideas, dissenting opinions, and important subtle points raised by group members are included as comments in the data set.

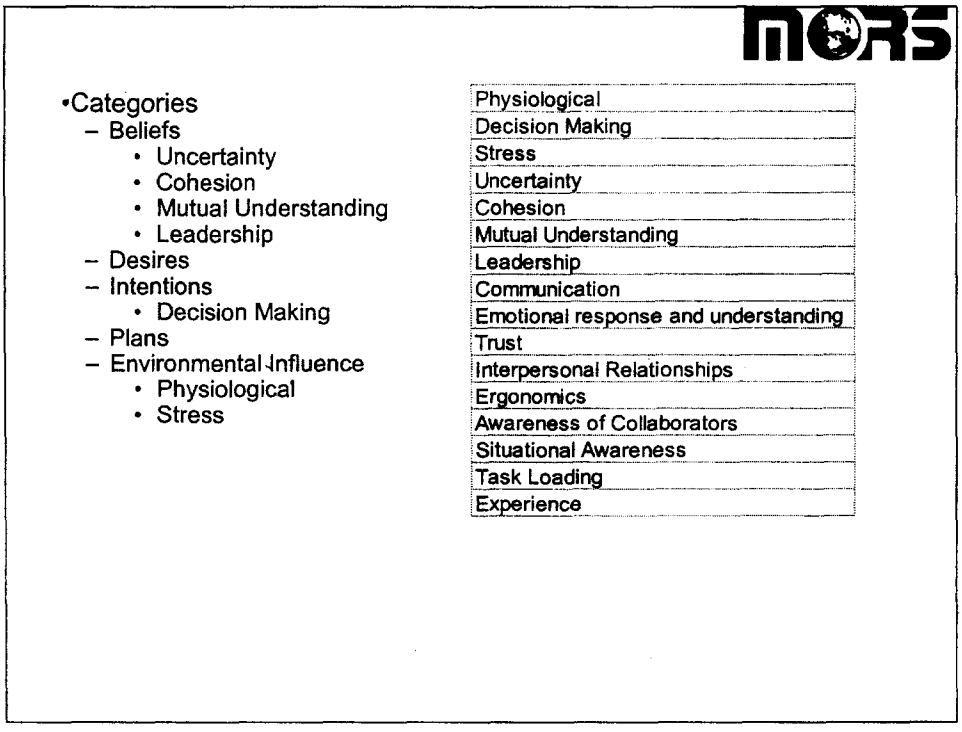

MCRS
Backup Slides

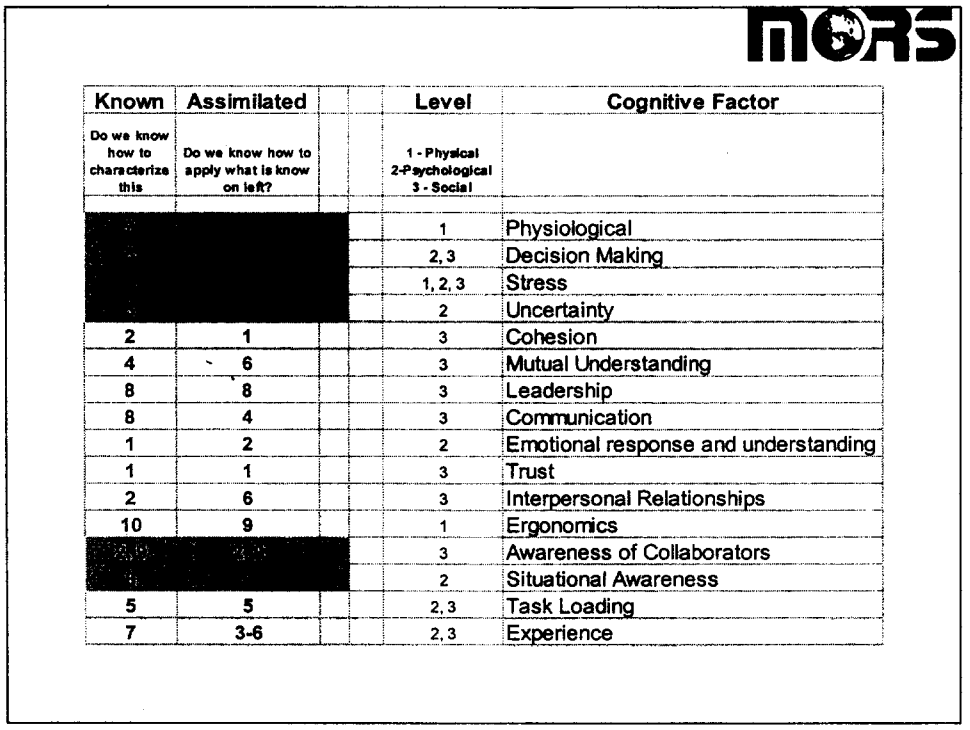
Discussions

- Zimm's Welcome
- Introductions
- Modifications of taskings
  - Why are we looking at cognitive factors to begin with? Do the proposed questions accurately capture what we should be focused on?
  - How do we model?
  - How do we aid decisions?
  - How do we follow through to OOTW?
  - How do we backstop decisions?

Tasking

- Tasking One – What classes of cognitive and behavioral factors are currently recognized in Command and Control?
  - From C2 Manual
    - Physiological
    - Decision making
    - Stress
    - Uncertainty
    - Value of cohesion
    - Trust and mutual understanding
    - Leadership
    - Communication
    - Emotional response and understanding
    - Trust
    - Interpersonal relationships
    - Ergonomics
    - Awareness of collaborative work
    - Task loading
    - Experience
  - Command and control is the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission.
  - What don't we understand enough to implement?
  - Classes of behavioral factors
    - Bias – Internal factor that affects cognitive process
    - Conceptual Model – Understanding of context and standardization of terms
    - Environment
      - Do we change the C2 systems so they're relevant to the environment?
    - Controls
    - Human reactions to information given
  - Individual context can have a large effect on how fuzzy language is interpreted.
  - While Warfare is an "art," at one time all sciences were "art"
  - Artificial Intelligence (AI) has problems in that it can not detect when assumptions underlying rule sets have been violated.


MORS
•Categories
– Beliefs
• Uncertainty
• Cohesion
• Mutual Understanding
• Leadership
– Desires
– Intentions
• Decision Making
– Plans
– Environmental Influence
• Physiological
• Stress
Physiological
Decision Making
Stress
Uncertainty
Cohesion
Mutual Understanding
Leadership
Communication
Emotional response and understanding
Trust
Interpersonal Relationships
Ergonomics
Awareness of Collaborators
Situational Awareness
Task Loading
Experience



Known	Assimilated			Level	Cognitive Factor
Do we know how to characterize this	Do we know how to apply what is know on left?			1 - Physical 2-Psychological 3 - Social	
[redacted]				1	Physiological
				2, 3	Decision Making
				1, 2, 3	Stress
				2	Uncertainty
2	1			3	Cohesion
4	6			3	Mutual Understanding
8	8			3	Leadership
8	4			3	Communication
1	2			2	Emotional response and understanding
1	1			3	Trust
2	6			3	Interpersonal Relationships
10	9			1	Ergonomics
[redacted]				3	Awareness of Collaborators
				2	Situational Awareness
5	5			2, 3	Task Loading
7	3-6			2, 3	Experience

Working Group 2 - Future Outbrief

How Cognitive and Behavioral Factors Influence Command and Control

28-30 October 2003
The Institute for Defense Analyses
Alexandria, Virginia

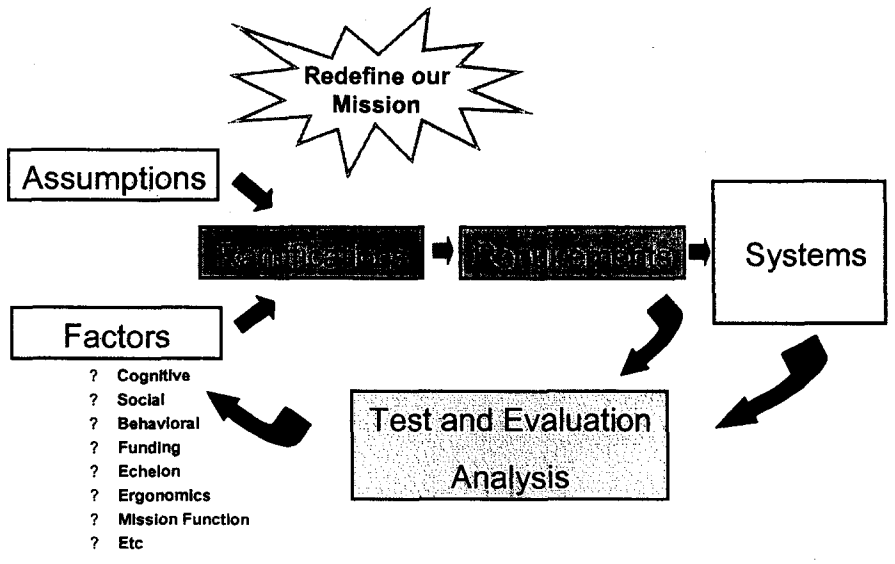
Participants

- Co-Chair Mr. Dave Garvey, Alidade, Inc.
- Co-Chair Dr. Kim Holloman, EBR
- Recorder Ms. Tina Brown, MITRE
- Mr. John Rice, COMOPTEVOR/NAVSEA CDSA
- LTC Mike Flynn, Combined Arms Doctrine Directorate
- Dr. Stan Halpin, ARI
- Mr. Andy Rumbaugh, AFSAA/SAF
- Dr. Michael Bernard, Sandia National Labs
- Dr. John Warner, ARL
- Dr. Tom Allen, IDA

Taskings

- WG 2.1 - What are some of the ramifications of cognitive, behavioral and social factors on future command and control systems?
- WG 2.2 - When planning for future command and control systems, how should system requirements be written to include the effects of cognitive, behavioral and social factors on command and control processes?

Group 2 Mission Process



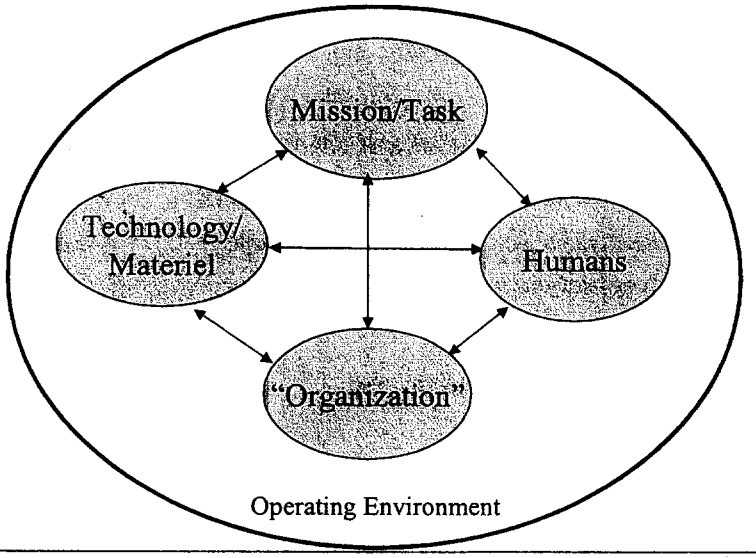
Key Terms

- Command and Control
- System
  - Network (social - hardware - holistic)
- Concepts of Command and Control
  - Procedural/ROE (detailed command)
  - Creative problem solving (mission command)
- Social factors
  - Collaboration, virtual teams
  - Collective action
- Knowledge vice information

Key Points and Lessons Learned

- Cognitive and Behavioral → Cognitive and Social
- Holistic view of the "system"
- Focus should be on understanding/meanings rather than more information
  - Capacity does NOT equal capability
  - The right information does not necessarily lead to "right" responses
- Procedures/ROE versus creative problem solving
- The value of the system should be evaluated based on the improvement of human mission performance and outcome effectiveness
  - Evaluation should be on-going throughout system development and deployment
- R&D must focus on cognitive and social factors

Holistic View of C2 "System"



Future C2 Requirements Should Address

- Agility
  - Adaptive
  - Responsive
  - Flexible
  - Innovative
  - Multi-functional
  - Robustness and resilience
- Distributed Collaboration
- Devolution of decision making authority
- Deployable
- Continuity of operations
- Operable across entire range of military operations
- Improved interoperability/integration across Services, agencies, coalition and others (technical, semantic, conceptual)

Human Cognitive Enablers

- Creativity
  - Thinking by analogy
  - Deductive reasoning
- Problem solving
  - Inductive (pattern recognition)
  - Deductive reasoning
- Agility (can use multiple methods to think)
- Self awareness (critical thinking)
- Learning capabilities
- Comprehension

➔ Humans are good at "Sensemaking"

Human Cognitive Constraints

- Memory
  - Limited capacity
  - Limited by experience
  - Tendency to "create" memories
- Pattern misrecognition
- Processing limitations can result in:
  - Inappropriate heuristics
  - Confirmative bias
  - Etc.
- Emotion
- Stress response
- Fatigue

➔ Humans are not just information processing machines!

Social Enablers and Constraints

- Trust
  - Preference for face to face interaction
  - Multiplicity of immediate and long term goals
  - Importance of past performance
- Confidence in technological tools
- Uncertainty avoidance (fear of failure)
- Team "hardness" (experience together)
- Cohesion (shared purpose)
- Joint/Interagency/Multinational (JIM)
- Organizational learning

Ramifications of Cognitive and Social Factors on Future C2 Systems (1)

- C2 system is inherently "social"
  - Need to focus beyond "individual"
  - Teams, Teams of Teams, Organizations
- Need to better match knowledge skills and abilities to job/specialty requirements
  - Job Task Analysis
  - Recruiting, training, retention and promotion
- Need better designed job/specialty requirements to better incorporate human cognitive/social factors
- Need to support a range of command and staff processes
  - ROE/procedures vs. creative problem solving
- Need to account for end - end costs
  - Hidden cost of neglecting cognitive factors
  - Unintended consequences (+/-)

Ramifications of Cognitive and Social Factors on Future C2 Systems (2)

- Must avoid digital divide(s)
- System must be designed to compliment human capabilities
  - Tailored to build on inherent strengths of humans and to overcome limitations
  - Technology should leverage human strengths, not just expect those strengths to overcome system shortfalls

C2 System Requirement Concepts

From Cognitive Ramifications

- Advanced decision support to enhance understanding and meaning versus more information
- Intelligent information management is needed

From Social Ramifications

- Knowledge acquisition and sharing embedded in system
- Creation and support to communities of practice

→ All of these will need to be reflected in Joint Capability Development System documents and service procurement directives

How to Reflect the Human in Writing Future C2 Requirements

- Iterative process
  - Top down: incorporates theoretical/empirical knowledge of cognitive and social factors
  - Bottom up: incorporates operator insights (OEF, OIF, experiments, simulations, etc.)
- Include appropriate measures and metrics
  - Ongoing and continuous test and evaluation
  - Focus on effect of technology and materiel on human performance

Nothing's equal!

$\neq$

Working Group 3 – Implementation Outbrief

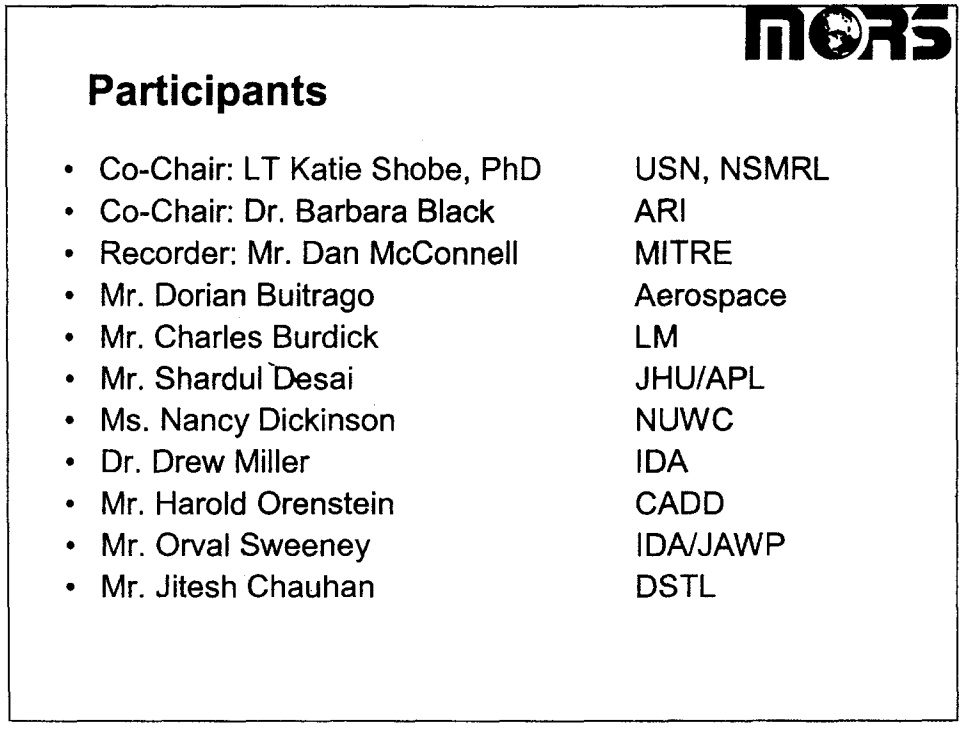
How Cognitive and Behavioral Factors Influence Command and Control

28-30 October 2003
The Institute for Defense Analyses
Alexandria, Virginia

Taskings

- WG 3.1 - Given that social scientists have knowledge about the potential impact of a given cognitive or behavioral factor, how can this knowledge be implemented in command and control processes, technologies, and training?
- WG 3.2 - What barriers currently exist in implementing such knowledge? What impact do time and resource constraints have on our ability to consider and include cognitive and behavioral factors? Are these barriers the result of gaps in research and development? How can those barriers be overcome?
- WG 3.3 - Produce a generic recommendation list for inclusion in the workshop exposition that describes cognitive and behavioral requirements, issues, and capabilities that should be considered when contracting for, and developing, command and control processes and technologies.

These are the 3 questions we were given to answer.



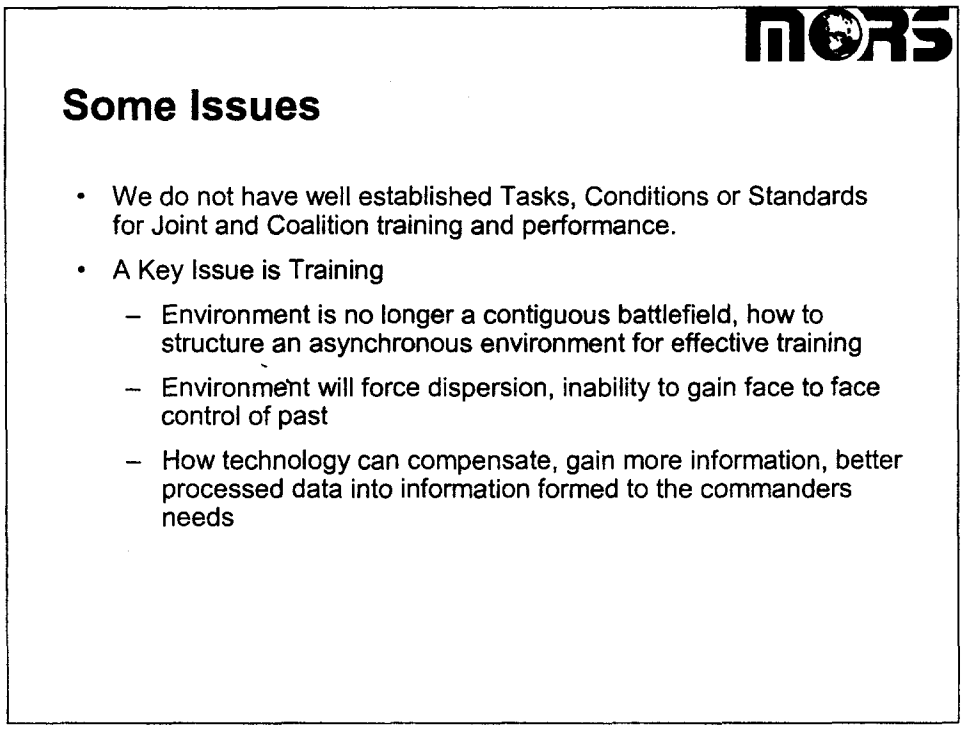
As you can see, we had a diverse group that crossed services and countries.

Some Issues

- Reverse the train of thought from "we have this technological capability and those humans keep messing it up" --
  - What are the human behavioral considerations
  - Compounded with net centric considerations of dispersion, etc,
  - How to augment the human support tools
  - Commanders traditionally want eye contact, can VTC substitute?
- Questioned whether the focus should be on the individual commander on a collaborative group of commanders or both.
- Echelon: What level of decision making should be considered? – Strategic (NSC – Combatant Command) or Operational (JTF)?

Before we tackled the specific questions, we pondered some issues in general concerning cognitive factors in command and control. In the past, typically the technology would be built and then the human operator would have to adapt to learn how to operate the system. We agreed that we need to reverse this thinking – better to take into account the human factor prior to planning the technology.

Another issue was the level of focus for our task, whether it is the individual operator/soldier or the team? Moreover, there could be teams of teams, as evidenced in netcentric warfare. The principles that govern behavior may change depending on the level of focus.



A new area of concern is Joint and Coalition training. How do we measure performance in these new configurations if we don't have established tasks, conditions, and standards? We may have a firm grasp on individual level of performance measures, but not at this new level.

Training emerged as an important issue. Training could potentially counteract the effects of poor design of technology if conducted the right way. Moreover, training should mimic the conditions that the operators/soldiers will face during real operations, such as an asynchronous environment. An interesting point of discussion was the change from face to face communications to digital or computer communications. This change forces the communications to lose some important components of human interaction, such as facial gestures, change in voice, etc.

Question 1

Given that social scientists have knowledge about the potential impact of a given cognitive or behavioral factor, how can this knowledge be implemented in command and control processes, technologies, and training?

Our first question.

High Level Implementation Summary

High Level Implementation			
	Process	C2 Technology	C2 Training
Behavior Cognitive Decision Making	1) modelling (wargames and sims) algorithms, data, validation 2) R&D 3) tradeoff studies 4) incorporate human factors/MOPs/standards into the capability development processes, I.e.conceive, brainstorm, tradeoff, prototype and analyze in experiments	1) testing/training 2) system performance 3) R&D 4) performance methods 5) acquisition human interface standards -interference -standards -RFPs ORDs 6) functional/ performance specs 7) training documentation (manuals, etc.)	1) performance standards 2) performance methods 3) MOPs 4) training exercises

Our Working Group was split on how to address this question, so we provided two answers. The first group's results, shown here, focused on a high level of how behavior, cognitive, and decision making factors could be implemented in command and control processes, technology, and training.

Detailed Implementation Summary: The Problem

Problem	C2 process 1	C2 process 2	C2 process 3	C2 process 4		
	Info Gathering	Decn Making	Communicating	Feedback/NCW	C2 Technology	C2 Training
Cognitive Factors (Behavior/Aspects)	1) data overload	1) groupthink 2) (decision paralysis)	1) bottlencks 2) unanalyzed data	1) real time filtering	1) lack of objectives for system development 2) Bandwidth 3) no standards for non-ergonomic cognitive factors for systems design	1) how to recreate a thinking enemy
Human Performance (Behavior; indiv or team)	1) fatigue/physio stress 2) signal detection & classification	1) fatigue/physio stress adverse effects are exacerbated 2) allowing for creativity while adhering to standards	1) language barriers 2) cohort issue 3) service culture	1) digital systems - alerts/shared knowledge 2) analog systems -manual processing 3) COA analysis & wargaming	1) need to accommodate individual differences	1) how to create a physiologically realistic friendly/ enemy situation
Command Style (interpersonal behavior)	1) striking the balance of staff autonomy and cmd directed necessity 2) varying levels of micromanagement involved for subordinate action	1) striking the balance between consistency (standards) of decisions with creativity and initiative 2) influence of negative command climate	1) degradation of VTC capability 2) balance in battle preparation and comms to accommodate robust plan adjustments	1) identifying causal results attributing cognitive factors 2) capturing the logic/reasoning involved with actual decisions	1) automating capture of tagged data to subjective data 2) design specificity between staff and command requirements	1) how to compensate for absence of experienced commander 2) training criteria to establish effective command styles 3)need to represent asymmetric/foreign command styles

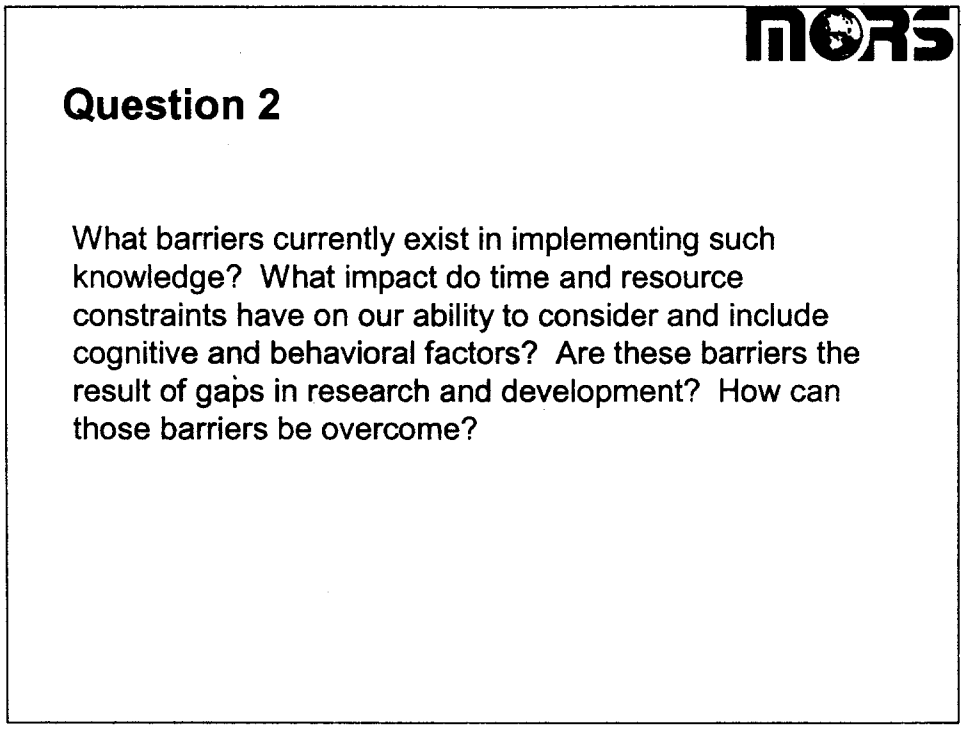
The second group's focus was more detailed than the first group, and they felt that the answers provided on the previous slide were too general to be useful. Additionally, in order to address the question they felt it necessary to define the problem areas first for various command and control processes (information gathering, decision making, communicating, and feedback), technology, and training.

Detailed Implementation Summary: Implementation

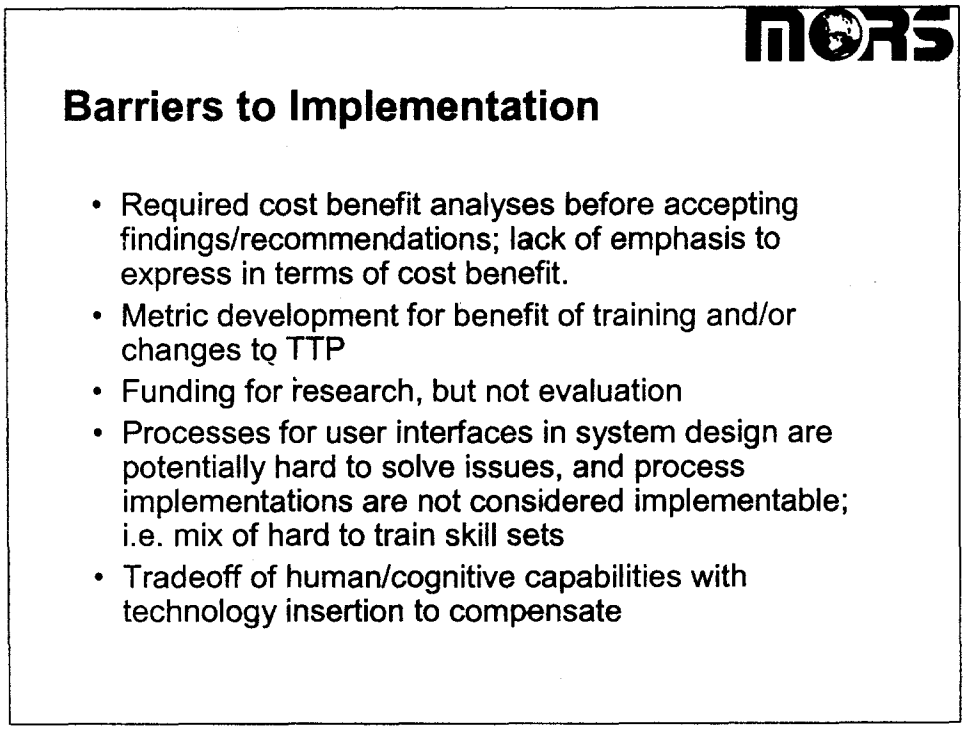
Implementation	C2 process 1 Info Gathering	C2 process 2 Decn Making	C2 process 3 Communicating	C2 process 4 Feedback/NCW	C2 Technology	C2 Training
Cognitive Factors (Behavior/Aspects)	1) relevance 2) filters 3) data aggregation	1) exercises 2) Trained facilitators 3) mentors	1) training in relevant service/coalition language and cultural differences	1) processes to check for receipt/ misunderstanding critical orders	1) include cognitive scientists in all phases of acquisition 2) use of portal technology 3) visualization technologies	1) include cognitive scientists in IPTs 2) develop performance standards
Human Performance (Behavior; indiv or team)	1) using staff interactions to determine collection priorities 2) integrating performance degradation studies with doctrine		1) consolidate or centralize effort to research/ understanding implications of Reachback in various types of employment e.g. UAV, vehicle maintenance, medical consultation, etc.	1) Joint training 2) end of every NCW training exercise should assure HEMP destroys all electronics - continue to fight without NCW	1) modularity and sellorability solutions 2) early use of HITL simulation in design and Development, e.g. systems integration labs	1) need for training SIL 2) integrating performance degradation results into simulations/other training models 3) end of every NCW training exercise should assure HEMP destroys all electronics - continue to fight without NCW 4) training differences between more modular force structure and unit replacement policy
Command Style (interpersonal behavior)	1) experimenting with situational styles to dermine guides for particular situations 2) staff training for different echelons	1) In training focus on creativity aspects of DM and capture data relating to environmental factors	1) experiment with differing Cmd styles during controlled info gaps and battle prep	1) allow cognitive scientists to participate in various operations to record selected metrics 2) gain closer access to Cmdrs pre/post activity	1) incorporate techn expertise into decisio making process	1) ensure in individual, collective sequencing o training, it includes new or alternative technology approaches /capabilities 2) C2 training in command style and cultural awareness

This slide depicts the proposed solutions to implementing cognitive factors in command and control based on the problems identified in the previous slide.

It should be noted that we acknowledged that these factors, both across the columns and down the rows, were not exhaustive and represented our biases.


MORS
Question 2
What barriers currently exist in implementing such knowledge? What impact do time and resource constraints have on our ability to consider and include cognitive and behavioral factors? Are these barriers the result of gaps in research and development? How can those barriers be overcome?

Question 2

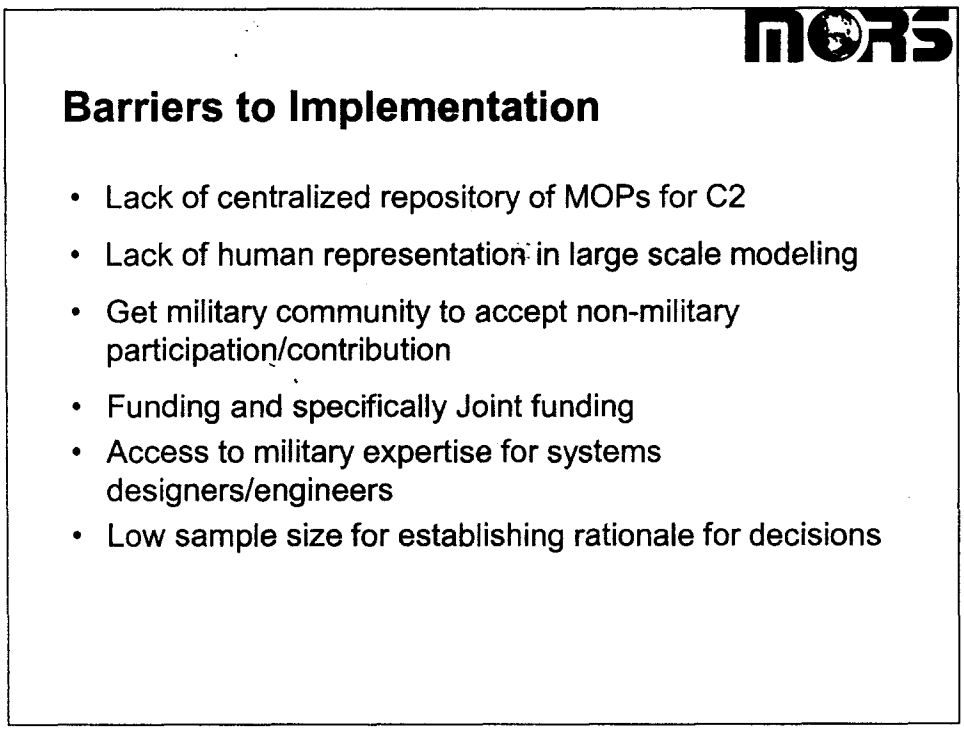


One of the major barriers implementing our solutions is that there is no standardized way to document the benefit in cost if human factors are factored in the design process vice if they are not. Given this absence of empirical evidence of the value added, we felt that the military community would be hesitant to heed our advice.

Barriers to Implementation

- Shortage of social scientists/analysts (and/or $) in the services for Network Centric Warfare (NCW) planning; time to grow expertise
- Failure to fully advantage service capabilities, e.g., roles for organizations, like ARI and/or JTCG/HE (Joint Technical Coordinating Group/Human Effectiveness), to incorporate into other analytic teams
- Not identifying where get the most bang for the buck by including or emphasizing human element
- Inadequate human in loop simulation or testing in conjunction with virtual testing

Another barrier to implementation is the shortage of experts to provide the needed input on cognitive factors. This idea is coupled with the problem of getting the military to use the existing facilities and capabilities that could provide direct support for implementing cognitive factors. These capabilities exist across services, but given the lack of funding it is difficult to "get their name out there" as a source of knowledge.

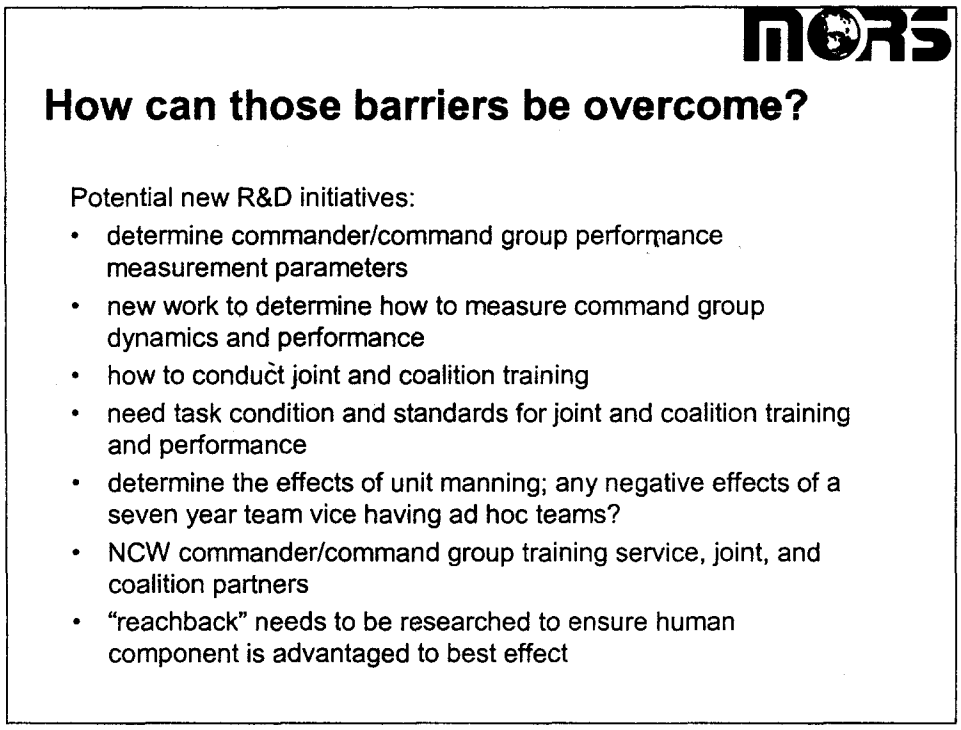


Other barriers to overcome include those that are cultural, such as acceptance of DoD civilian and industry experts as valuable participating partners by the military community. The stovepiped attitudes of the services related to supporting/funding Joint work also constitute barriers. Some barriers are an inherent part of measuring C2 in operational environments such as low sample sizes and nested independent variables (e.g., brigade, battalion, company in the Army).

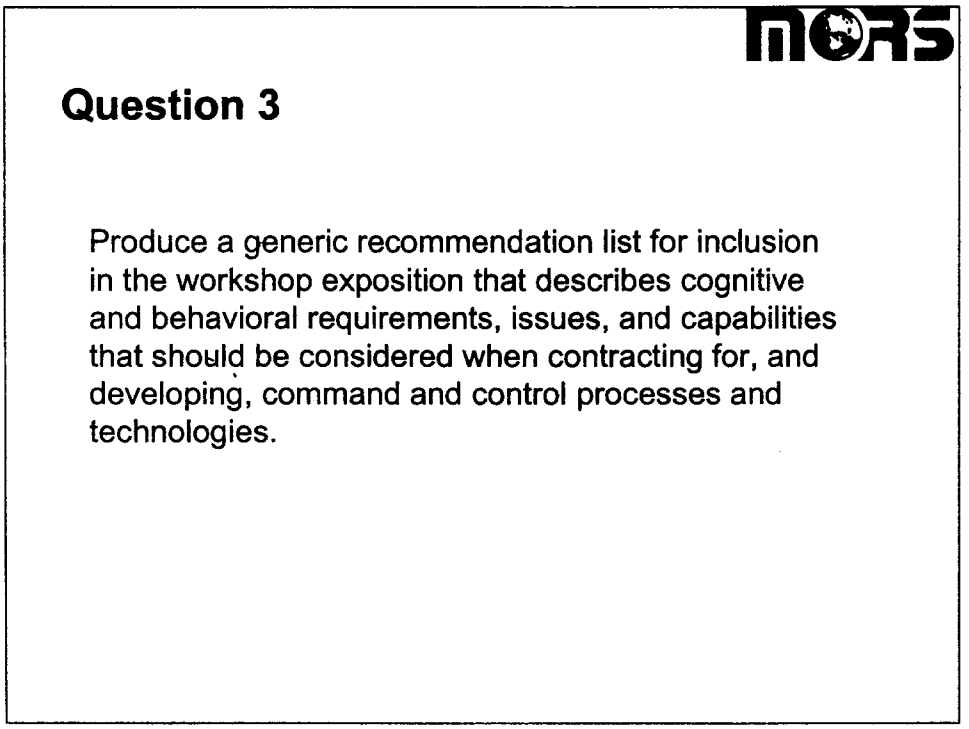
Barriers to Implementation

- Risk aversion
- Lack of quantification for expert judgment
- Over reliance on metrics for complex decisions/giving inadequate emphasis to the things you can't quantify or measure
- Military culture is cautious to accept social/behavioral measurement and recommendations
- Lack of cognitive/behavioral science information with implementation implications/guidelines in doctrine or military education

Traditionally, cognitive/behavioral science data is thought of as "soft" in comparison to data from the physical sciences, since behavioral data may rely on expert judgment that lacks the quantification and "rigor" of other disciplines. The result may be, as stated in the third bullet, an "over reliance" on what "can" be measured "easily" instead of potentially more important aspects that are not as easily quantified.



While the effort will not be slight, and there will be considerable time and cost associated with success, the group listed a number of suggestions for overcoming these barriers. For example, initiating major R&D work in relevant areas: human performance measurement, joint and coalition training, and value of decreasing personnel turbulence through stabilized tours of duty.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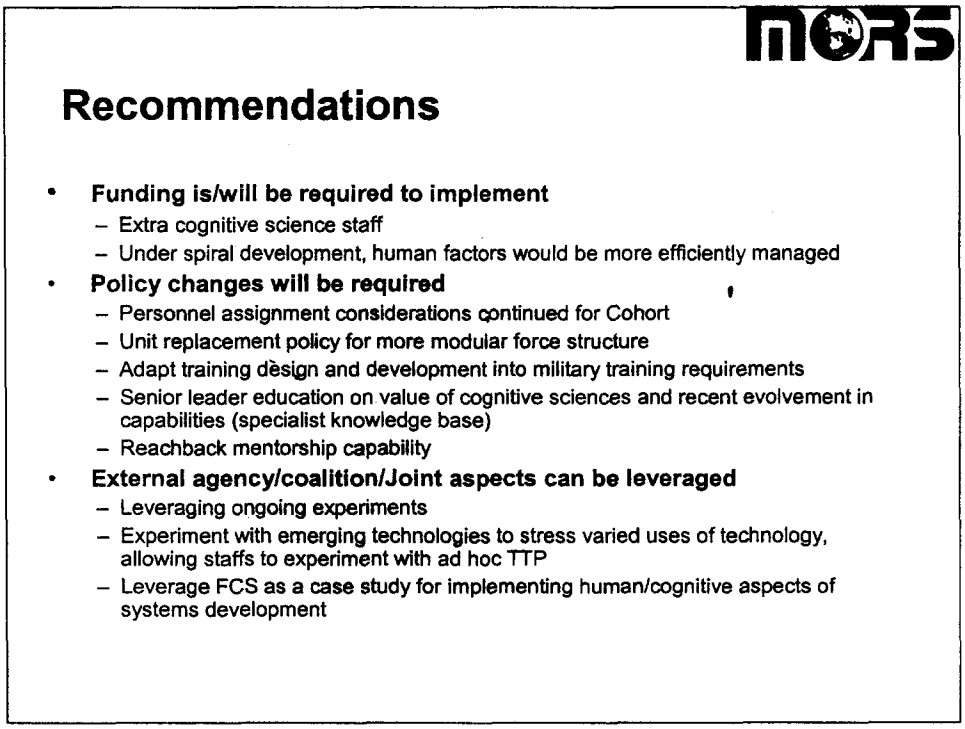
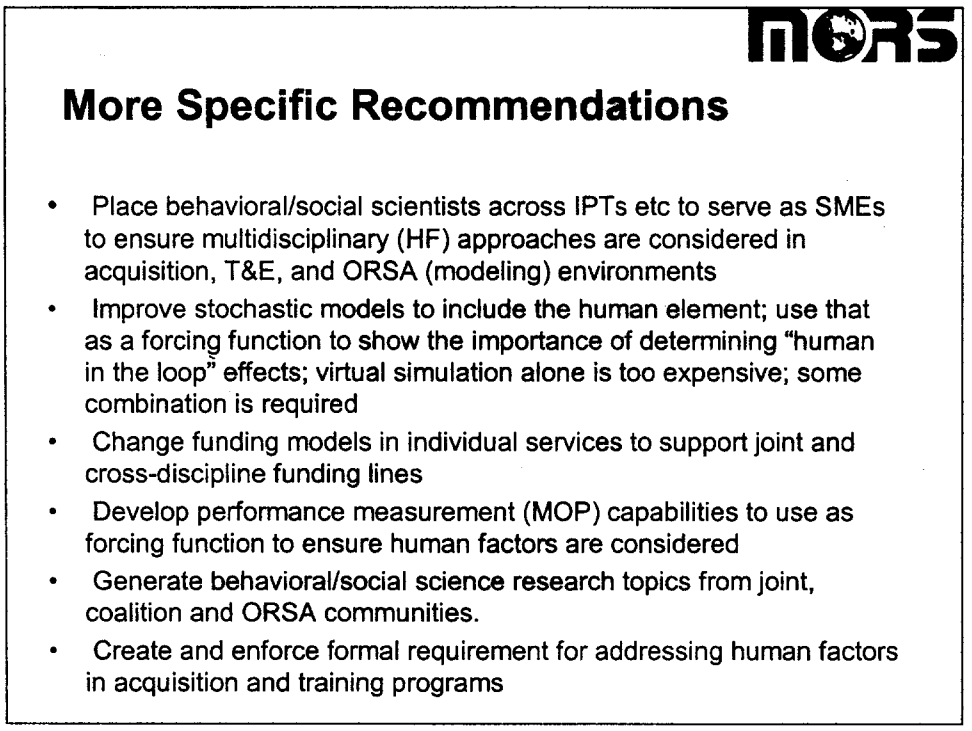
Question 3
Produce a generic recommendation list for inclusion in the workshop exposition that describes cognitive and behavioral requirements, issues, and capabilities that should be considered when contracting for, and developing, command and control processes and technologies.

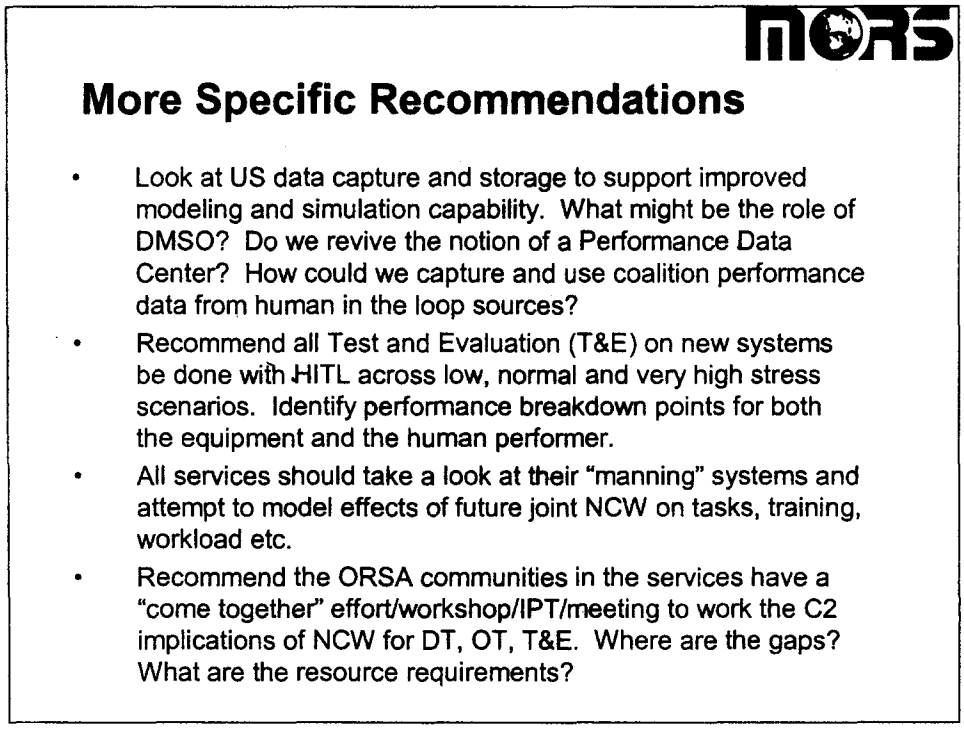
Question 3



Recommendations fell into three major categories: funding, policy and JIM (joint, interagency, and multi-national).



The group attempted to articulate several specific recommendations.



Of course the final recommendation was to have another meeting.

More Specific Recommendations

- Consider implementation of the approach that begins with Human-in-the-Loop (HITL) simulation (virtual) and takes those small scale results to feed stochastic models whose results will dictate the next iteration of HITL experiments. (a la the test fix test approach)
- Determine how to ensure the military community writ large recognizes the behavioral/social scientists as resources that can add value.
- Determine how to effect a cultural change in both program managers and contractors to consider and use HITL simulation.
- All systems in design/development (SDD) phase should incorporate procedures to ensure that the PM has addressed the impact degraded mode operations have on human performance, e.g., EMP destroys electronics. Impact of degraded modes on training requirements (e.g., increased numbers of tasks to be trained/sustained) also must be assessed. This requires appropriate performance measures in order to assess the combat effectiveness.

Working Group 4 - Methods
Annotated Outbrief

How Cognitive and Behavioral Factors Influence Command and Control

28-30 October 2003
The Institute for Defense Analyses
Alexandria, Virginia

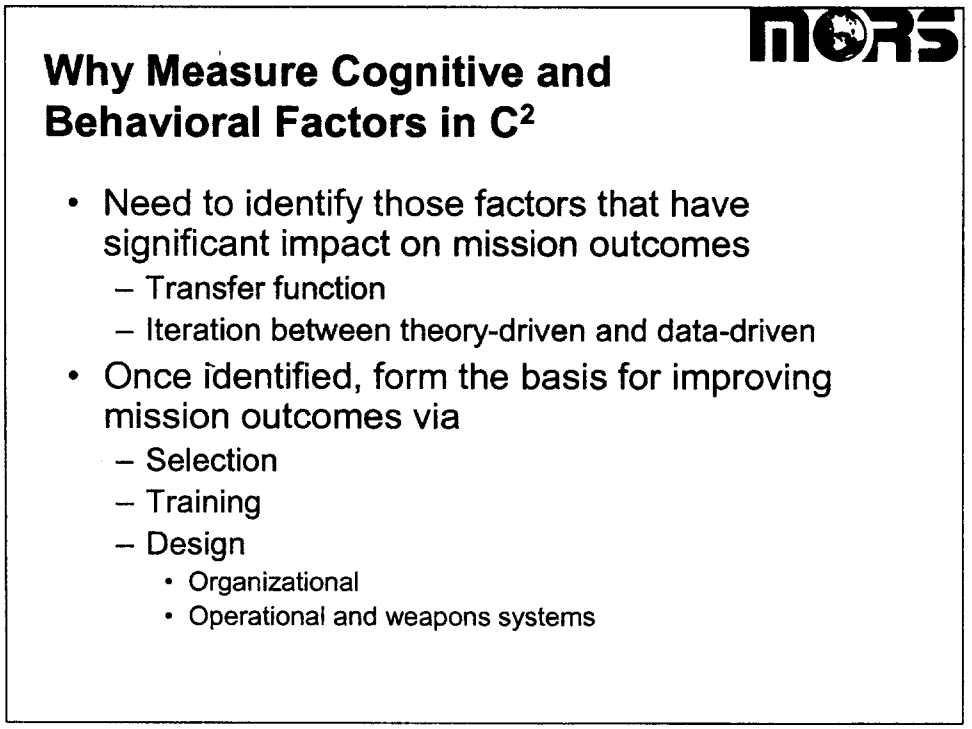
MORS

Taskings

- WG 4.1 - Identify methods that can be used to study and measure the influence of cognitive and behavioral factors on command and control structures, tasks, processes, and technologies.
- WG 4.2 - What is the status of current methods? What are the attributes and limitations of those methods?

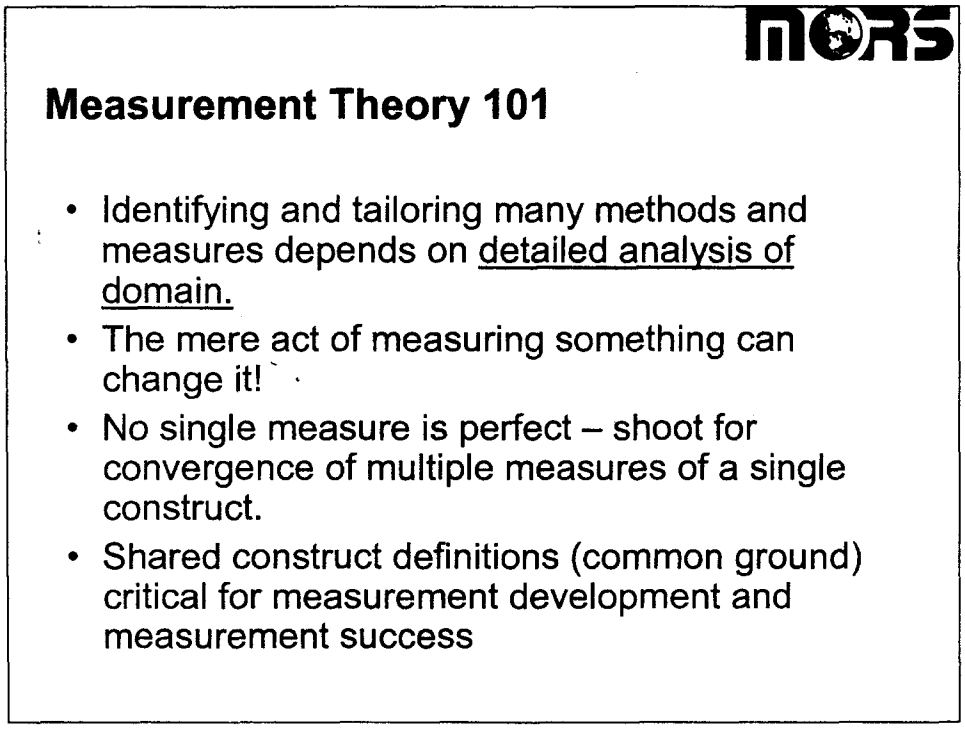
Participants

- Co-Chair: Dr. Lyn Canham, AFOTEC
- Co-Chair: Dr. Gwendolyn Campbell, NAVAIR
- Recorder: 1stLt Lindsey Schmidt, USAF, AFOTEC
- Ms. Shirley Bergstrom, JMACA JT&E
- Mr. Robert Holcomb, IDA
- Dr. Salvatore Schipani, ARL
- Mr. John Stoffel, Joint Warfare Analysis Center
- Ms. Laura Marie Stuart, Joint Warfare Analysis Center
- Mr. Charles B. Taylor, DARPA
- Mr. Andrew Thompson, Joint Warfare Analysis Center
- Ms. Diane Ungvarsky, ARL
- Ms. Corrine Wallshein, AFSAA/SAPI
- Mr. Jon Stoffel, Joint Warfare Analysis Center



We start with the question of "Why?" – why bother to measure cognitive and behavioral components associated with humans in command and control? Our answer: We need to be able to identify those factors that have a significant impact on mission outcomes. Once we can identify which factors matter, we can begin to improve mission outcomes by (a) selecting for people who have the "right" characteristics, (b) training those people to come to each new mission with the "right" declarative and procedural knowledge and (c) designing our organizations and equipment to provide the optimal support for those individuals and teams.

More specifically, we need to identify the transfer function(s) that map inputs (including cognitive and behavioral factors of the human component) to measures of mission outcome. We need to be able to quantify the impact that changing one of those factors (whether it be less training, less experience, more aversion to risk, better situation awareness (SA), or whatever) is likely to have on mission outcomes. Our best bet at identifying this transfer function is to use both theory-driven and data-driven methods. Let theory suggest candidates, but make sure data support claim that those factors are accounting for significant and unique amounts of variance in mission outcomes (or dump them) and let our data tell us if we are still missing important factors.



We start by following the example of some of our speakers on the first day of the mini-symposium, by presenting a mini-tutorial on Measurement Theory.

While some candidate factors can (arguably) be measured in a context-free way, such as personality traits like extroversion/introversion, many of our methods and measures are context-dependent. The key to a good methodology and set of measures/metrics is a good analysis of the domain.

Measurement Theory 101

- Methods of Study
  - Laboratory versus Field
  - Factorial versus Representative Design (Brunswik, 1956)
  - Human Participants versus Modeling and Simulation
  - Reliable patterns versus Critical Event Based Analysis
  - During mission/training exercise versus any other time

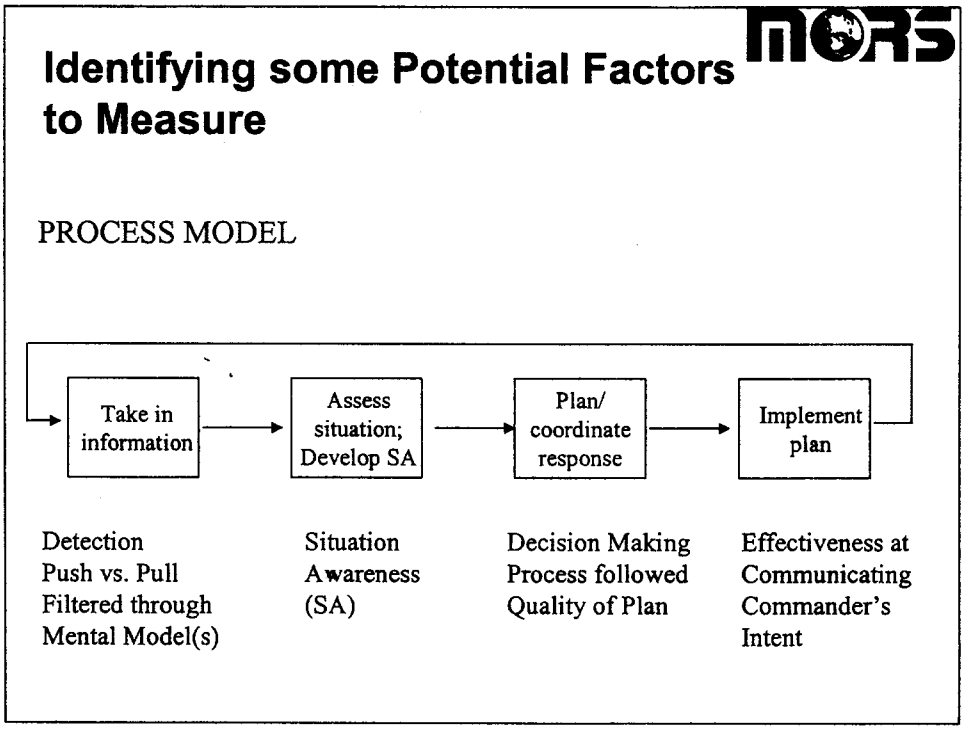
Hammond, K. and Stewart, T. (2001). The Essential Brunswik: Beginnings, Explications, Applications. Oxford University Press.

For an overview on methods and measures to study decision making, with emphasis on Brunswik's Lens Model, see:

Cooksey, R. W. (1996). Judgment Analysis: Theory, Methods and Applications. San Digeo, CA: Academic Press.

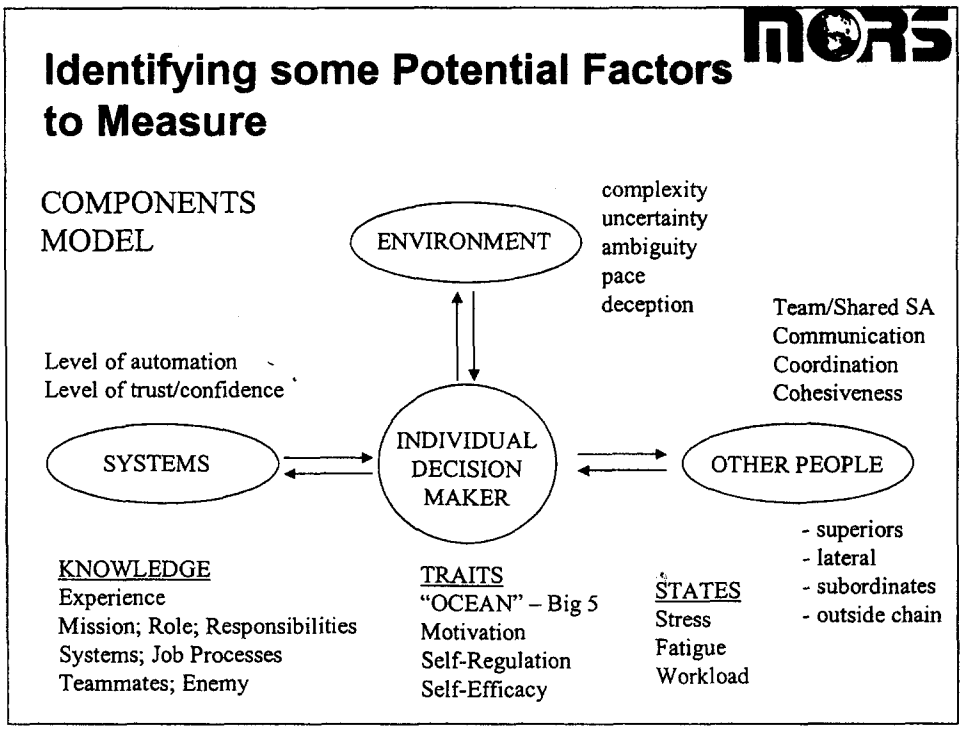
Measurement Theory 101

- Measurement Dimensions
  - Objective versus Subjective
    - Subjective includes participant self-report and Subject Matter Expert (SME) assessment
  - Process versus Outcome
  - Individual versus Team versus Organizational
    - The whole is more than the sum of it's parts
  - Quantitative versus Qualitative
  - Relative Assessment (norm-referenced) versus Absolute Assessment



In order to attack our assigned questions of identifying methods and measures to study cognitive and behavioral factors, we needed to start with a list of the factors that we might want to study. We decided to generate candidate factors within the context of two highly simplified models of command and control. In no way are we claiming that these conceptual models are "right" or "comprehensive" – they were good enough to serve our purpose. They allowed us to generate a semi-organized list of candidate cognitive and behavioral factors that could be studied in the context of command and control.

This is a "process" model that suggested factors such as situation awareness, decision making process, information flow, communication, etc.



This "components" model identified a number of other factors such as states and traits of the individual, the nature of interpersonal relationships, trust in automation, etc. that could be measured within a command and control context.

Big 5 reference – there is currently a 5-factor model of personality that is generally accepted in the personality theorist community. Those factors include:

O – openness; flexibility

C – conscientiousness

E – extroversion

A – agreeableness

N – neuroticism

Measuring Information Flow/ Available Information

- Quantity and timing of message traffic
- Actions applied to messages
  - Deletion, saving, opening, amount of time open, passing (and to whom?)
- Analyses of flow of information
  - Link analyses
  - Push/pull analyses
- After action interviews focused on:
  - Who knew what?
  - When did you know?
  - What else did you want to know?

In this section of the brief, we have selected several of the cognitive and behavioral factors previously identified and detailed techniques for studying, measuring and (sometimes) analyzing them.

With regards to information flow, we focused on message traffic (acknowledging that information comes in other forms).

What measures can you derive from behavior "in situ"?

1. There are objective, quantitative measures associated with the quantity and timing of message traffic. Note: the environment provides natural windows when actions may be taken effectively and when they are physically impossible. For example, once a plane is a certain distance away from a ship, traveling away at a certain speed, it is no longer physically possible for a combat air patrol to catch up with it. This type of environmental affordance allows us, in some cases, to assess the timeliness of the arrival of a message. (In other words, if the message suggests an action should be taken, does the message arrive when there is still enough time left to take the action effectively?)

2. While we can't know for sure if a person processes and comprehends the information in a message, we can certainly determine whether or not the message was even opened, how long it was left open on the monitor, and whether or not it was passed to the appropriate people at the appropriate time. These data can suggest the presence or absence of comprehension.

3. There are established techniques for analyzing information flow, including link analyses (who got what from whom when?) and measures such as the ratio of pulled information (requested) to pushed information (automatically supplied).

What additional measurement techniques do you have available?

1. Interviews and/or verbal protocols. You rely on subjective reports. Many potential weaknesses – memory failures, hindsight biases, etc. These are also difficult to analyze. But still a potential source of useful information.

Measuring SA Precursors

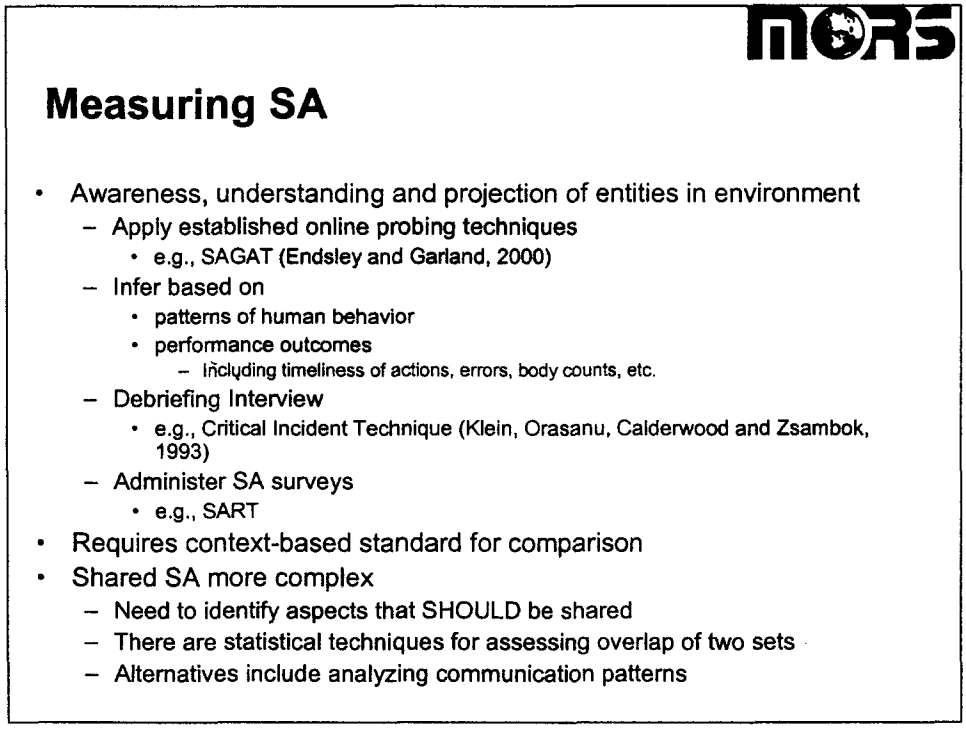
- Match between Characteristics of Information ("ground truth") and Perception of Same
  - Reliability, relevance, availability, accuracy, quality, usefulness, timeliness, completeness, source
  - Measuring perception
    - Ask them
    - Infer based on behavior
  - Measure reality
    - Depends on characteristic

We believe that a precursor to good SA is the extent to which a person's perception of the nature of the information-rich (or data-rich) environment around him is well calibrated to the actual environment. For example, does the person know which information is reliable? Which is relevant? Etc.

Assessing this requires two separate assessments – the person's perception and "ground truth."

With regards to measuring "ground truth", in some cases there are objective measures available (certain pieces of equipment have known reliability values) and in some cases (such as information relevance) you may need to fall back on subject matter expert assessments.

With regards to measuring a person's perceptions you basically have two categories of methods – 1) making inferences based on their behavior and 2) asking them.



Endsley, M. R. and Garland, D. J. (2000). Situation Awareness Analysis and Measurement. Mahwah, NJ: Lawrence Erlbaum Associates.

SAGAT – Situation Awareness Global Assessment Technique

SART – Situational Awareness Rating Technique

Klein, G.A., Orasanu, J., Calderwood, R. and Zsambok, C.E. (1993). Decision Making in Action: Models and Methods. Norwood, NJ: Ablex.

Measuring Decision Making Factors

- Characteristics of Decision Maker
  - e.g., decision style, risk tolerance, values
    - Measurement techniques: inventories
  - e.g., experience, training
    - Measurement techniques: objective numbers
- Identifying Decision Making Processes
  - Technique: Policy capturing (Hammond, 1996)
  - Technique: Cognitive Task Analysis
    - e.g., Critical Incident Technique
- Outcome Measures
  - Decision time and accuracy
  - Completeness of plan (vis-à-vis contingencies, etc.)

Hammond, K.R. (1996). Human Judgment and Social Policy. New York, NY: Oxford University Press.

Measuring Individual Workload

- Validated Subjective Ratings Tools
  - NASA TLX (Task Loading Index)
  - SWAT (Subjective Workload Assessment Technique)
- Alternative Subjective Approaches
  - Subject Matter Experts observe and assess (rate) participant workload in real time
- Objective
  - Secondary task techniques
    - Infer based on performance on lower priority responsibilities
  - Task deferrals, shedding, work-arounds, strategy shifts
  - Number of tasks assigned within given time constraint
    - Caveat: May not match subjective ratings
- Physiological measures
  - Currently: Best for physical workload (e.g., heart and respiratory rate)
  - Emerging: Measures of cognitive activity (e.g., cortical activity)

Hart, S. (1980's). NASA report.

Measuring Team Workload

- Goals
  - Understand distribution of individual workload across team members over time
    - First step in supporting evenly distributing workload as much as possible
  - Capture mutual perceptions of team member workload
    - Which may influence teamwork behaviors
- Technique: Team Workload Matrix
  - (Entin and Serfaty, 1999)

Entin, E. and Serfaty, D. (1999). Adaptive team coordination. Journal of Human Factors, 41(2), 321-325.

Measuring Stress

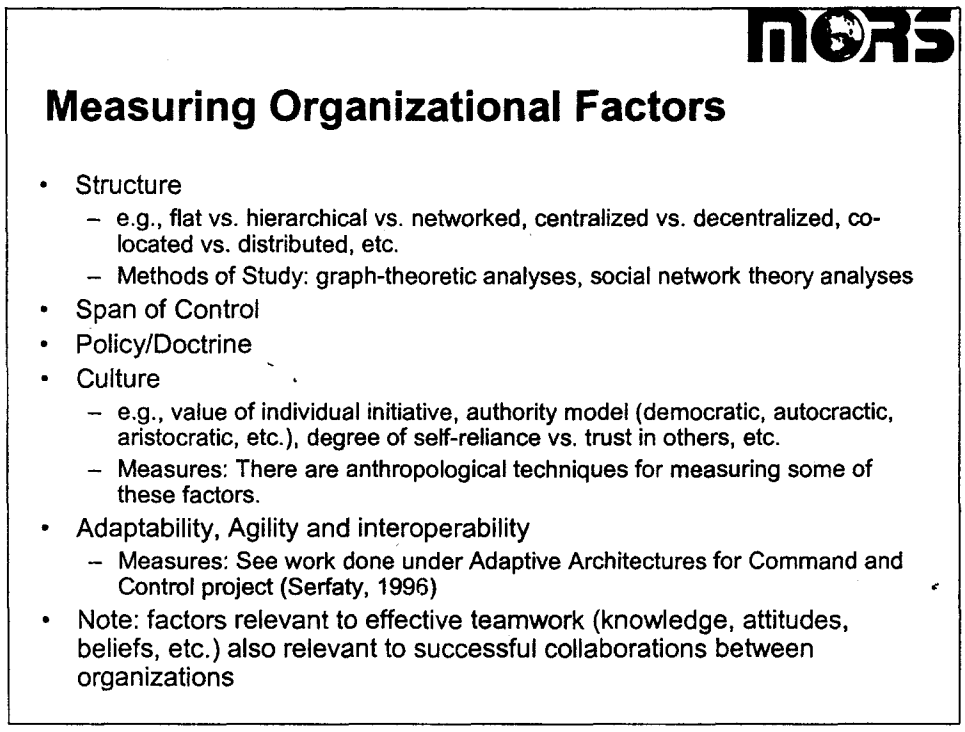
- Methods and measures available to address stress are analogous to those available to address (individual) workload.

Measuring Fatigue

- Objective
  - Number of hours of sleep deprivation
    - Established standards for what counts as "getting sleep"
  - Ratio of and schedule between work activity and break time
  - Error and rework rates
- Physiological
  - Respiration rate, glucose levels, salivary amalase, MRI, evoked potentials, etc.
- Subjective
  - Crew Status Survey (Developed by Air Force Flight Test Center)

Measuring Team-Related Factors

- Teamwork Skills
  - Factors: Compensatory behavior, coordination, communication, leadership
  - Measurement: Anticipatory behaviors, Windows of Opportunity-based assessment, SME ratings, team member reports
- Knowledge
  - Factors: role responsibilities, teammate characteristics, (dynamic), team structure and processes, own responsibilities and relationship within context of team and mission, etc..
  - Measurement: knowledge tests (may be scored against standards or assessed for agreement)
- Beliefs/Attitudes
  - Factors: Cohesion, team efficacy, trust, etc.
  - Measurement: Inventories such as Collective Orientation, Mutual Trust, etc.
- Objective Measures associated with time working together and time at particular position
  - May support inferences about team factors (skills, knowledge and beliefs/attitudes)



Serfaty, D. (1996). Adaptive Architectures for Command and Control (A2C2): An overview. Proceedings of the 1996 International Command and Control Research and Technology Symposium. Pp. 272-276.

MacMillan, J., Entin, E. and Serfaty, D. (2003). A framework for understanding the relationship between team structure and the communications necessary for effective team cognition. In Salas, Fiore and Cannon-Bowers (Eds) Team Cognition: Process and Performance at the Inter- and Intra-individual Levels. American Psychological Association.

Selected Methods: Attributes and Limitations

- Factorial
  - Attributes: Systematic and controlled analysis
  - Limitations: Can only address small (typically orthogonal) variable set
- Representative Design
  - Attributes: Greater external validity/generalizability
  - Limitations: Limited knowledge of individual variables
- Reliable Patterns
  - Attributes: Large set of established statistical techniques
  - Limitations: Only appropriate for domains that produce large quantities of decision making data
- Critical Event Based Analysis
  - Attributes: High potential for diagnosticity; Realistic
  - Limitations: Potential lack of generalizability; Difficulty in identifying and/or locating appropriate critical events
- Modeling and Simulation
  - Attributes: Faster collection of data under wider variety of conditions
  - Limitations: Lack of validated models

Selected Measurement Techniques: Attributes and Limitations

- Process (effectiveness and efficiency)
  - Attributes: Diagnostic (provides information necessary for outcome improvements)
  - Limitations: Necessary but not sufficient – must be linked with outcome information
- Outcome (effectiveness)
  - Attributes: Most relevant/important to community
  - Limitations: Necessary but not sufficient – must be linked with process information
- Assessment against others or self (norm-referenced)
  - Attributes: Permits comparisons between individuals and/or groups (grading on the curve)
  - Limitations: Can be costly/difficult to develop norm; doesn't necessarily tell us much about performance we need to be aiming for
- Assessment against "ground truth"
  - Attributes: Permits comparison against perfection (grading against the key)
  - Limitations: Not always possible (e.g., team cohesion and force effectiveness)

Significant Gaps in Method/Measurement Capability

- Fewer methods for studying teams and organizations than for individuals
- Improved interdisciplinary collaboration (cross-fertilization) across disciplines with methods/measures
  - OR, engineering, social sciences
- Transfer functions
  - Conceptual and quantitative relationships between factors and outcomes
- Methods and measures for data poor environments
  - e.g., red forces, coalition environments
- Taxonomy of missions with implications for
  - what cognitive and behavioral factors to measure (likely high drivers)
  - how to measure those factors
  - mapping between classes of missions and effective organizational designs

We have discussed limitations of specific methods and measurement techniques, but we also wanted to stand back and identify large scale gaps in our current capability. We believe that methods and measures for assessing individual and team factors are more highly developed than those for assessing organizational and societal factors.

We also do not think that all missions are created equal. A taxonomy that suggested which factors are likely to be high drivers and what measurement techniques are likely to be effective would be very valuable to the community. While this problem was not explicitly within our scope, we did end up identifying one potential classifying dimension - the extent to which the appropriate assessment of the situation automatically yields a solution (e.g., once you identify an air contact in Air Defense Warfare, all of your following actions are prescribed by Rules of Engagement) versus yields a problem solving technique (e.g., you now know that you have a resource allocation problem or a scheduling problem, but you do not have a solution to that problem yet and there are many possible solutions, each with their own pros and cons)

Take Home Message

- No "magic bullet"
  - Measuring complex systems with highly variable black box components (i.e., people) is difficult.
  - Perfect measurement is impossible.
- But, we do have methods and measures available
  - Have "full" tool box
  - Know strengths and limitations of each technique (tool)
  - Apply multiple measures and look for convergence
- Quantifying impact of human component on mission outcome is the only way
  - to participate in systems engineering and acquisition communities
  - to optimize our ability to contribute to mission success

References

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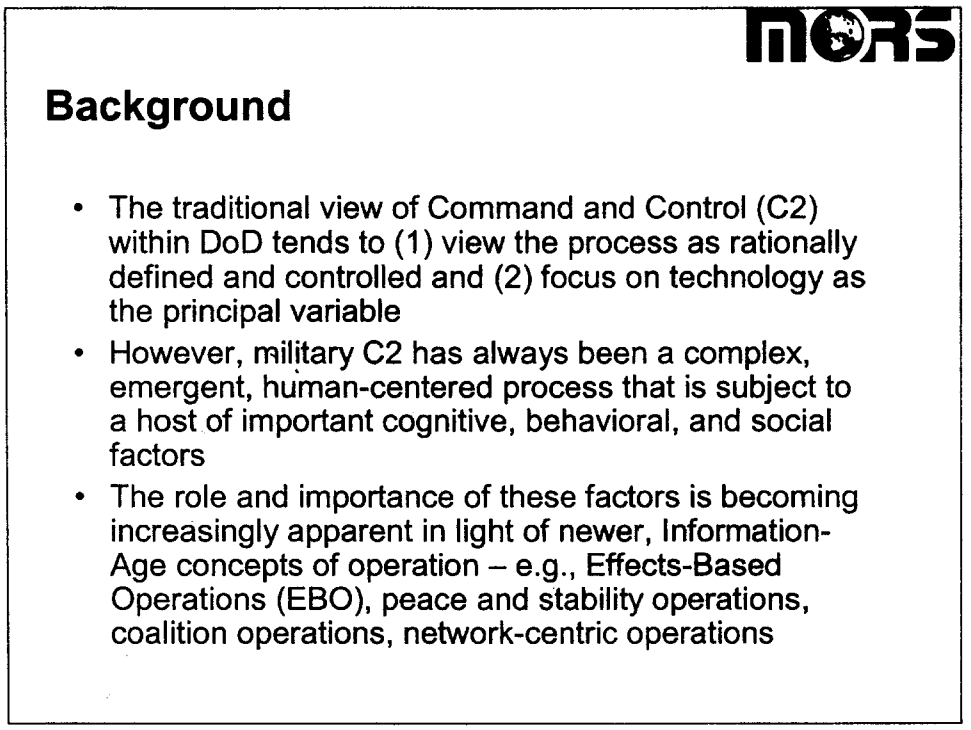
Synthesis Group Outbrief

How Cognitive and Behavioral Factors Influence Command and Control

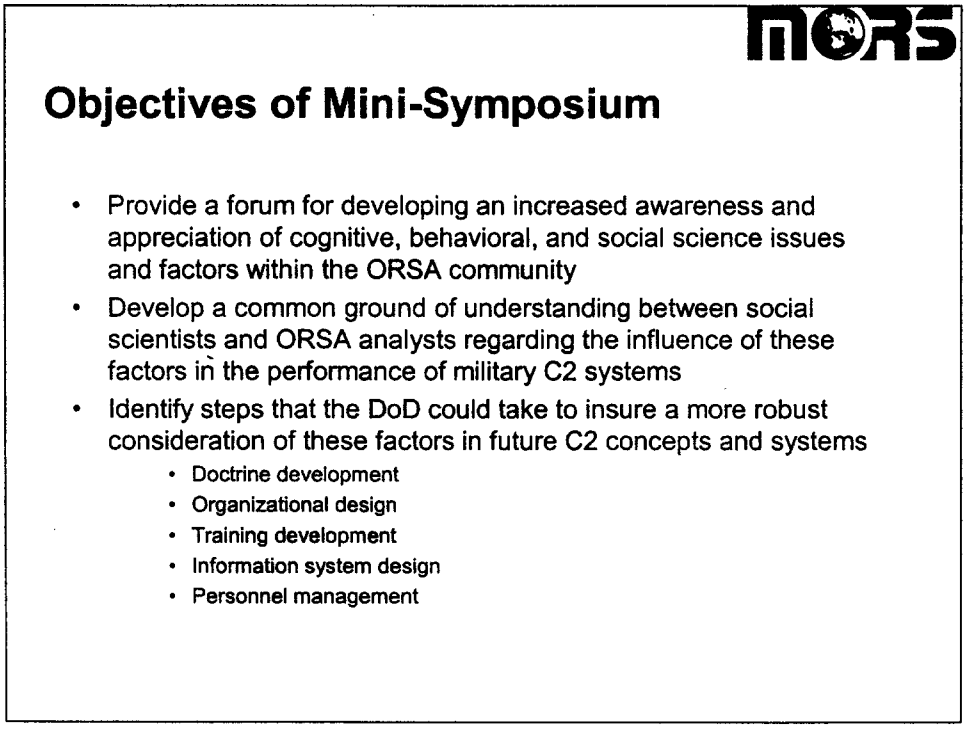
28-30 October 2003
The Institute for Defense Analyses
Alexandria, Virginia

This briefing presents insights developed by the Synthesis Group that participated in the Mini-Symposium.

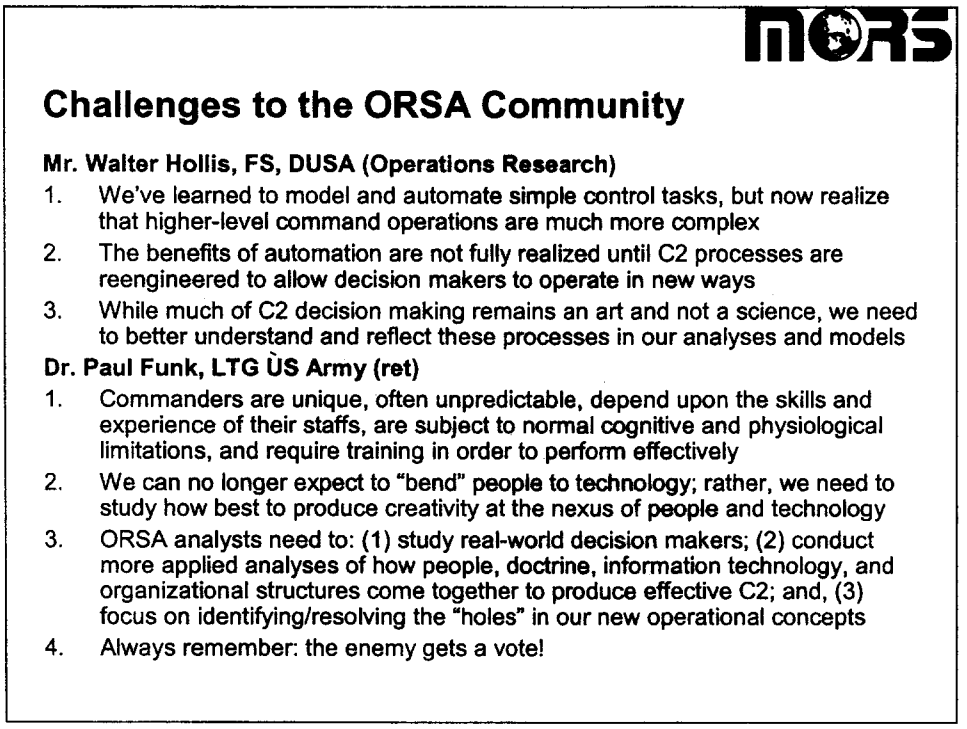
Members of the group are listed here. The group membership represented a wealth of experience in the analysis of military command and control systems and requirements, as well as being grounded in the relevant disciplines being discussed during the Mini-Symposium.



To set the framework for the synthesis of findings and insights, we first consider the background of this particular MORS meeting. As shown in this chart, the Mini-Symposium was motivated by the concern that the DoD has too often viewed C2 narrowly in terms of information technology and communication systems. Hence, the desire was for this meeting to focus on C2 as a complex, emergent, human-centered process that is subject to a host of cognitive, behavioral, and social factors. Throughout the meeting, emphasis would be given to highlighting the role and importance of these factors in C2 system performance — particularly in light of many of the newer operational concepts emerging within the DoD.

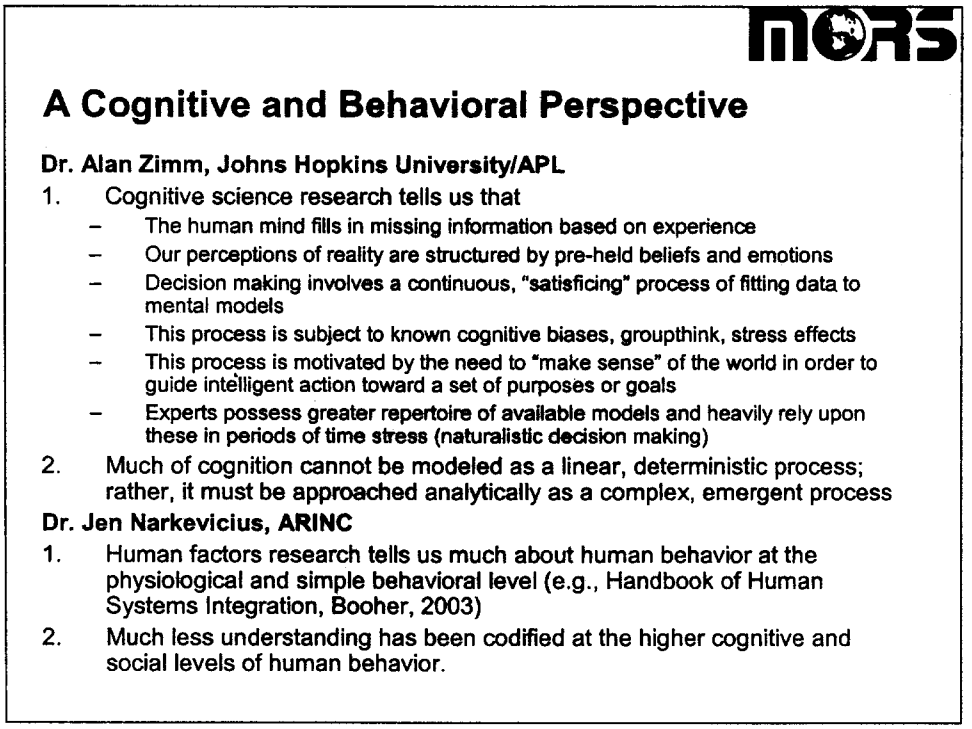


The specific objectives of the Mini-Symposium are shown here. First of all, the meeting provided a forum for the exchange of ideas between the social scientists and ORSA analysts. Second, it was envisioned that this exchange would lead to the development of a common understanding as to how various cognitive, behavioral, and social factors influence military C2 performance. Finally, it was envisioned that the meeting would identify steps that the DoD could take to insure a more robust consideration of these factors in future C2 concepts and systems.



The first day of the meeting was devoted to several plenary talks that would frame the scope and substance of the working group discussions that would follow on days two and three. In this regard, Mr. Walt Hollis, FS, led off by noting that the ORSA community has been studying C2 for several decades. We've learned to model and automate relatively simple control tasks, but now realize that higher-level command decision making operations are much more complex. While much of this decision making remains an art rather than a science, it is still important for the ORSA community to reflect these processes in our analyses and models.

LtGen Paul Funk USA (ret) then followed by sharing his perspective as a former division and corps commander. He described command decision making as a very human process — one that reflects human capabilities, limitations, and biases. He then challenged the ORSA community to develop a more systematic understanding of this process and how it contributes to operational effectiveness. Specifically, he cited the need for help in identifying and resolving various holes in some of the new operational concepts emerging from within DoD. Finally, he reminded the participants that war is still a very human process and that our adversaries always get a vote in each war's outcome.



Presentations by Dr. Alana Zimm and Dr. Jen Narkevicius led the participants through a basic review of what the social sciences have historically learned about human decision making behavior. In short, human decision making does not necessarily reflect the linear, deterministic paradigms often assumed in ORSA modeling and analysis. Rather, human decision making is subjectively guided by individual experience and often "satisficing" rather than optimizing in nature. What results is often a complex, emergent process by which humans take in salient features of their environment, make subjective sense out of this data, and translate it into goal-driven actions.

Understanding Decision Making

Human decision making has a complex and often non-analytic nature. Particularly in the case of key leaders who must operate in dynamic and uncertain operational environments.

Need for Improved Analysis

Col Phil Exner, USMC/OIF Combat Assessment Team

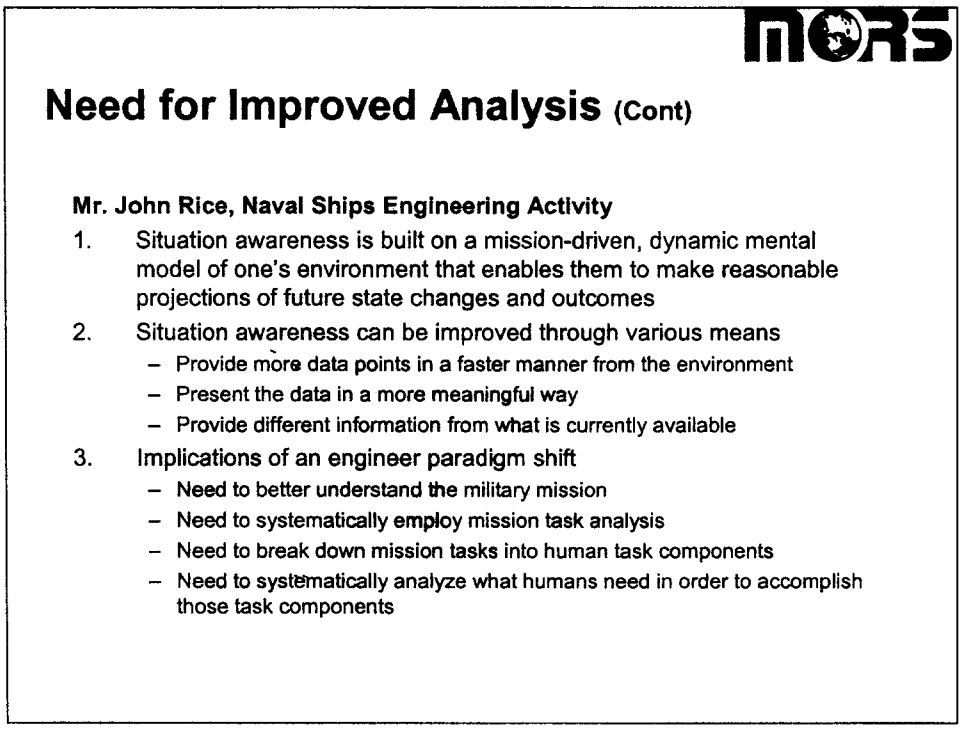
1. Broad consensus on problems, general agreement on factors, but divergent views on solutions
2. Example insights
   - Information capacity ≠C2 capability
   - Digital divide exists between higher echelon C2 and tactical C2 nodes
   - Commanders and staffs have insatiable appetite for bandwidth
   - BDA, IPB, and Intel could not keep up with pace of operation
3. USMC has demonstrated a field capability of collecting large volume of insights, but a better framework is needed for organizing them

Mr. John Garstka, OSD/Office of Force Transformation

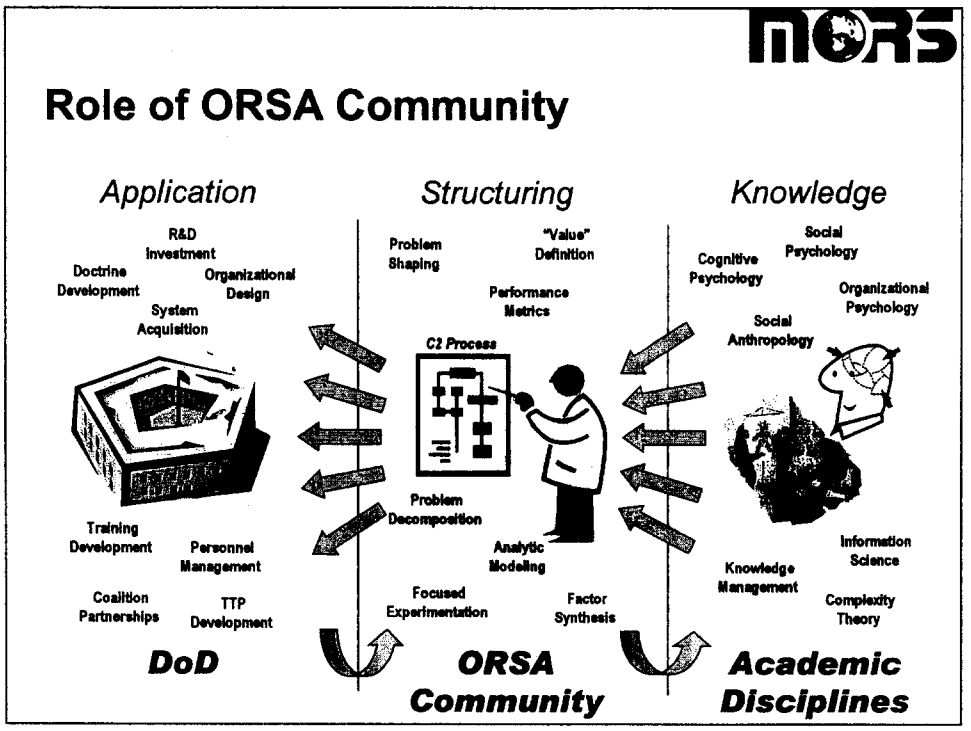
1. Information-Age Warfare requires integrated understanding of military operations across physical, information, cognitive, and social domains
2. Current case studies show that cognitive and social factors matter a lot for air, ground, maritime, SOF, coalition, and peacekeeping operations
3. General impression exists that better shared situation awareness improves combat effectiveness, but the ORSA community has provided few tools to empirically validate these types of hypotheses

Several other presentations emphasized the growing need for better tools and models for addressing cognitive, behavioral, and social factors in military C2. Specifically, Colonel Phil Exner presented recent insights from Operation Iraqi Freedom (OIF) that suggests that greater amounts of information bandwidth do not always translate into increased operational capability. He pointed out to participants that decision makers at lower, tactical levels of command did not always benefit from the information networks available to higher echelons and that the downward flow of Battle Damage Assessments (BDA) and other intelligence did not always keep up with the pace of operations at the tactical level. Overall, efforts like Col Exner's combat assessment team demonstrated that it is possible to collect volumes of meaningful data and insights from field operations. What is needed is a better analytical framework within which to organize and synthesize these insights.

Mr. John Garstka's presentation highlighted the need for analysts to address military concepts and systems across four domains of concern: the physical domain of the battlespace; the information domain of systems and networks; the cognitive domain of individual decision makers; and, the social domain of decision makers collaborating within and across various headquarters and other organizations. He also illustrated several case studies that suggest that increased shared situation awareness often leads to improved operational effectiveness. However, like several of the earlier speakers, he challenged the ORSA community to provide better models and tools that would help the DoD empirically validate these types of hypotheses.

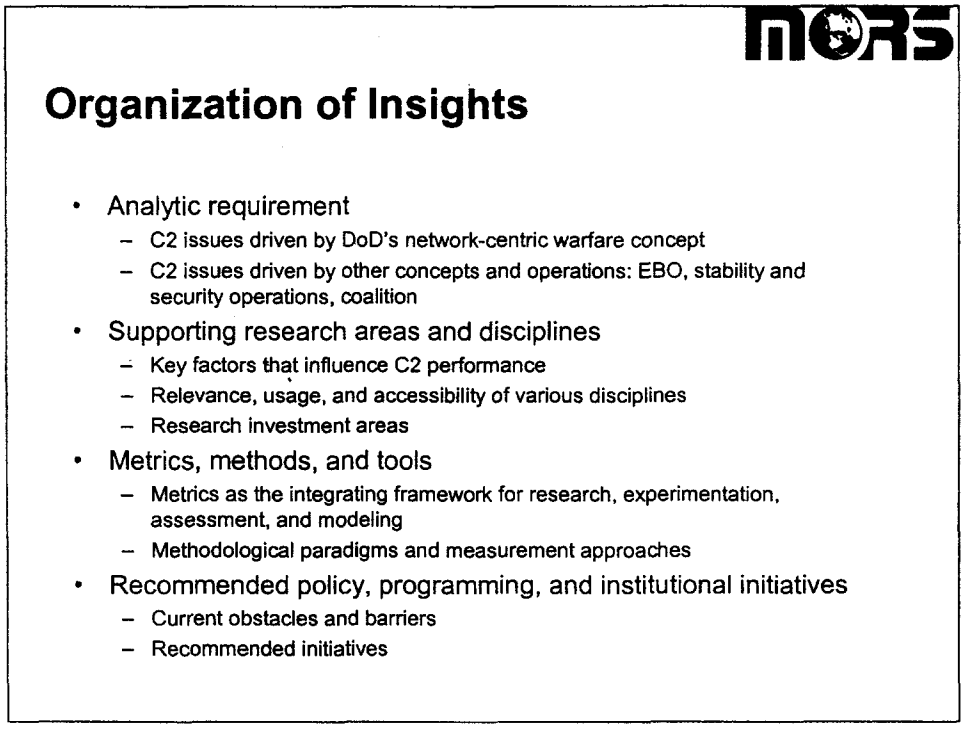


Mr. John Rice concluded day one with a discussion of situation awareness and how it can be improved through a variety of alternative approaches — e.g., more and faster data, improved presentation of data, more relevant data. The fact that alternative means — and DoD investment strategies — often exist for improving human decision making performance suggests the need for better analytic methods and tools for studying the relevant cognitive, behavioral, and social factors that influence military C2.

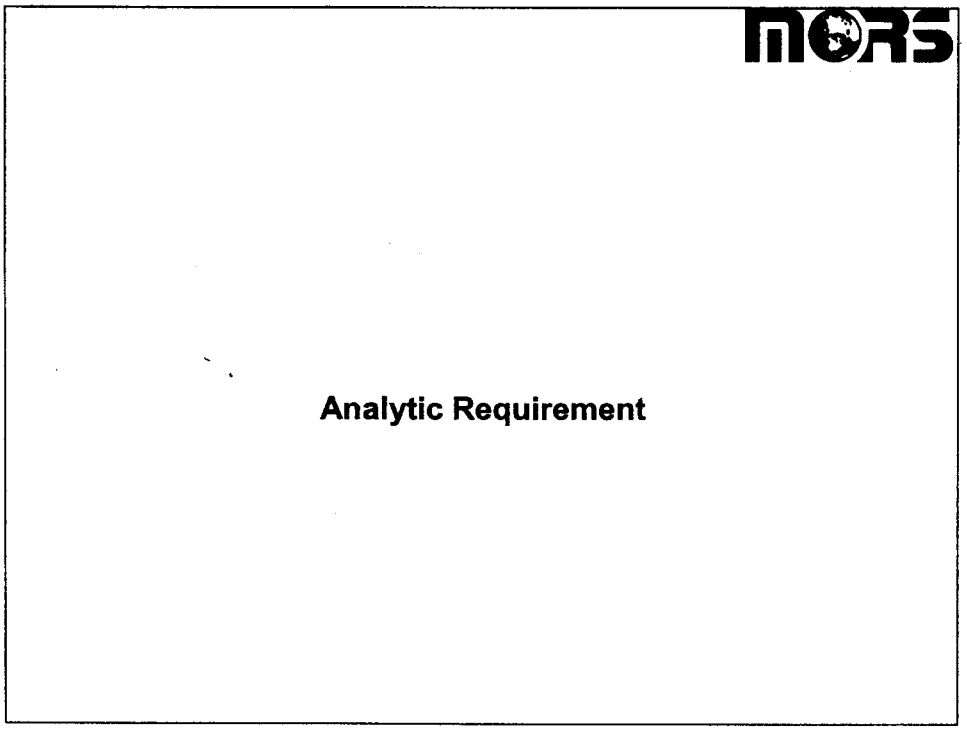


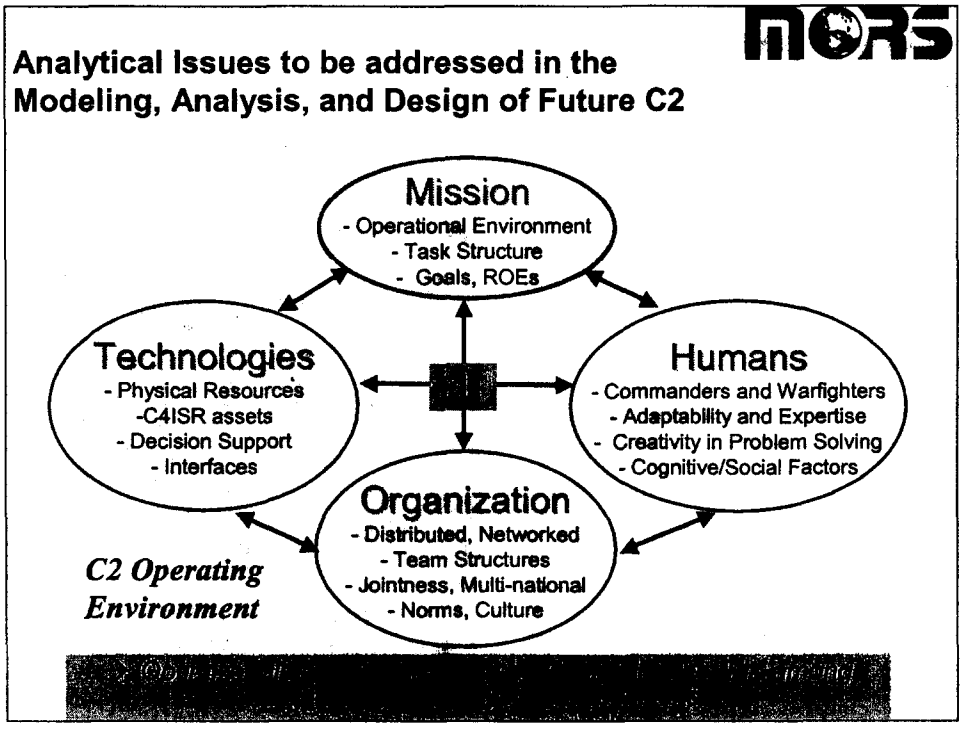
The issues identified on the opening day of the Mini-Symposium are summarized in this chart. On the right side of the chart we know that there are numerous academic disciplines and bodies of knowledge that can contribute to our understanding of C2 systems — what they are comprised of, how they operate, and what they potentially contribute to operational effectiveness. On the left side of the chart we can identify many areas of force development within the DoD that could immensely benefit from the application of these disciplines and bodies of knowledge. What is lacking — and has been lacking for many years — is an effective bridge between these two communities.

Herein lies the role of the ORSA community. What the ORSA community brings to the table is the ability to structure knowledge in meaningful ways that can guide intelligent policy formulation, investment planning, and force development within the DoD. Identifying what's important to consider in this structuring, what methods and tools are required, and what types of analytic paradigms are useful in developing this structure are all questions that lie at the heart of this meeting.



Following the plenary sessions on Day One, participants were divided into four working groups that addressed questions related to key factors, future requirements, implementation, and methods. Over the next two days, these groups engaged in open debate and developed various insights related to the objectives of the Mini-Symposium. Although each of these working groups developed a final briefing that highlighted specific insights from their discussions, it was the task of the Synthesis Group to integrate these insights into an organized whole. The framework used for organizing these insights is shown here — leading from the analytic requirement; to the relevant research areas and contributing disciplines; to the need for specific metrics, methods, and tools; to required policy, programming, and institutional initiatives that should be taken within DoD to promote application of these research areas to the analysis, design, and assessment of C2 systems.

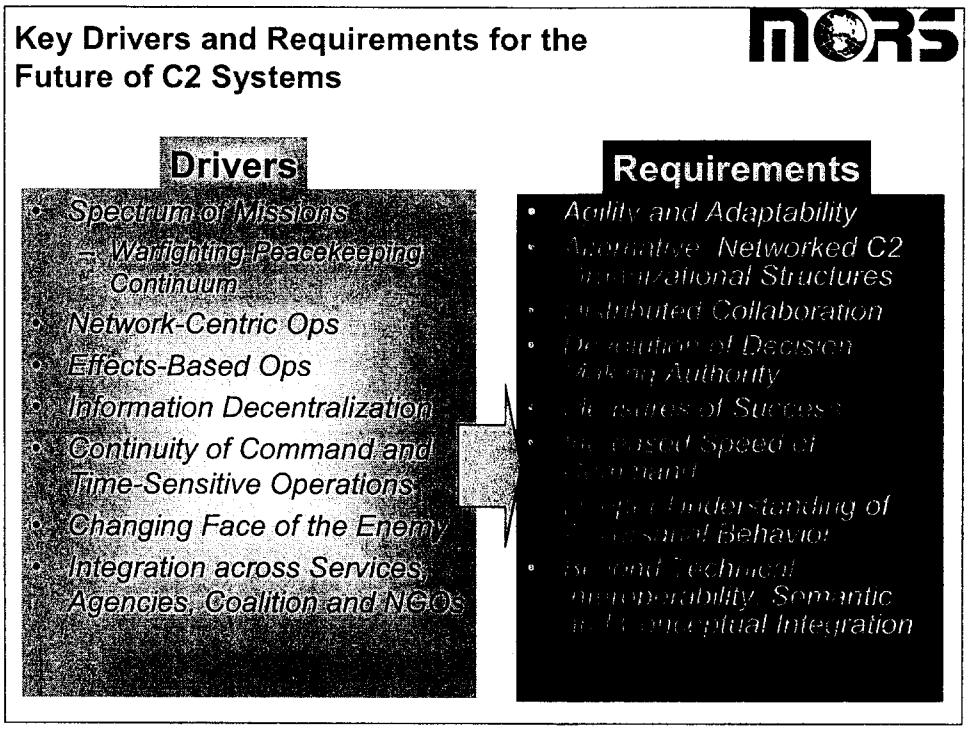

MORS
Analytic Requirement



To understand the analytical issues to be addressed in the modeling, analysis, and design of future Command and Control (C2) systems, we must first broaden our view of what constitute a C2 system. In the past, the narrow view conceived of the C2 (or C4ISR) system as a set of technologies designed to support a set of particular missions. We must extend this restricted perspective by including, in the C2 Operating environment, the human warfighters and the C2 organizations that support their performance in the battlespace. This is, in the words of OSD's John Gartska, and extension from the physical domain and the information domain to the cognitive and social domains. Without it the C2 system is not properly aligned, and its performance is bound to be sub-optimal.

One must first start with the MISSION. A modeling of the mission, including task analysis and decomposition, understanding of goals and constraints, as well as the overall Measures of Merit, should lead to the specification of technologies to best support the accomplishment, but also to the requirements for the competencies that the human warfighters should develop in order to best perform in this mission environment. Moreover the organizational structures (e.g., team, coalition, etc.) both formal, and informal must be specified.

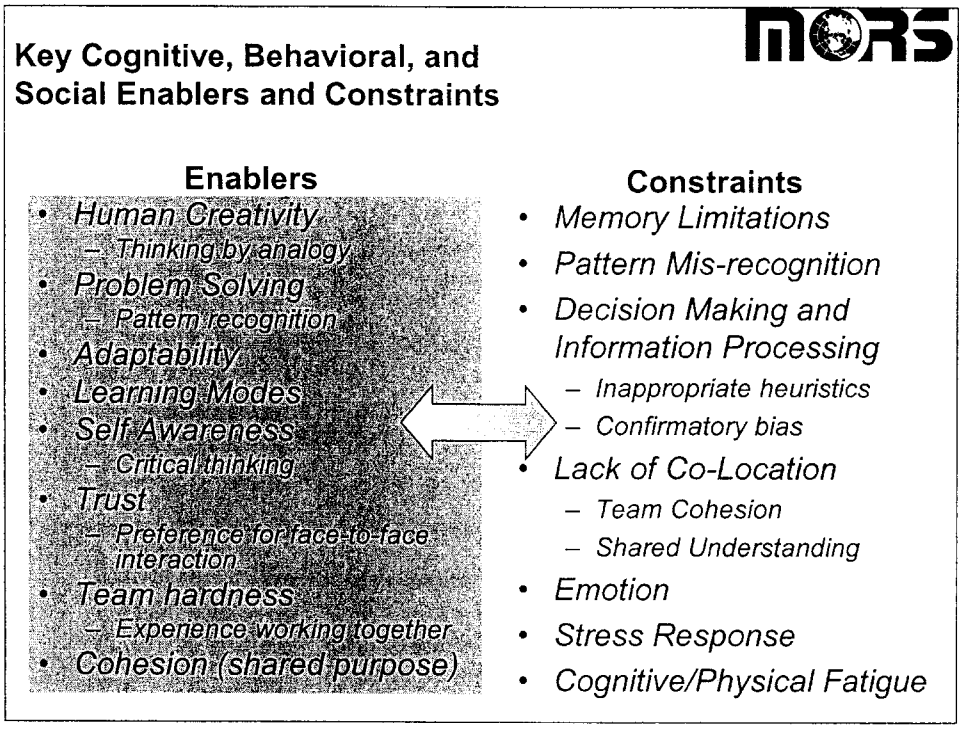
Thus: To *Optimize Mission Performance , one must Optimize the "Fit" among these Four C2 System Dimensions*



So what are the key characteristics or drivers and resulting requirements for these Future C2 Systems?

Without going into the details of specific operations, future ops have a set of common key drivers (listed on the left): Spectrum of Missions; Network-Centric Operations; Effects-Based Operations; Information Decentralization; Continuity of Command and Time-Sensitive Operations; Changing Face of the Enemy; and, Integration Across Services, Agencies, Coalition and Non Governmental Organizations (NGOs).

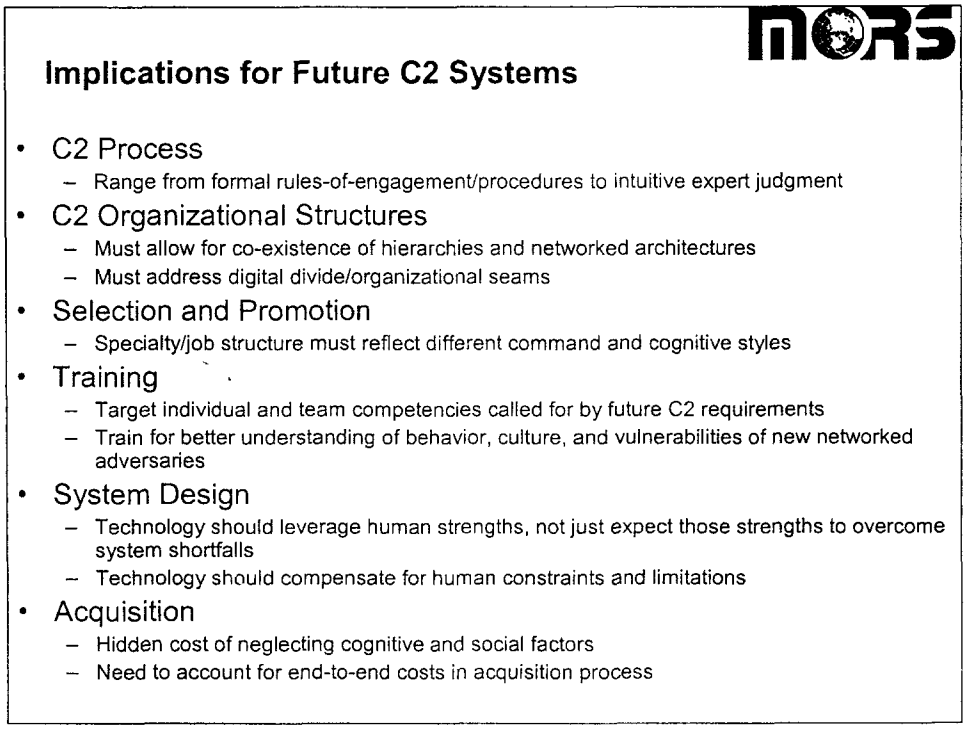
As a result, these drivers call for a set of human cognitive, behavioral and social requirements that will characterize all future missions (list on the right): Agility and Adaptability; Alternative, Networked C2 Organizational Structures; Distributed Collaboration; Devolution of Decision Making Authority; Measures of Success; Increased Speed of Command; Deeper Understanding of Adversarial Behavior; and, Beyond Technical Interoperability: Semantic and Conceptual Integration.



We must first understand, model, measure, and develop the human enabling factors that are necessary to fulfill the requirements listed in the previous chart. Some of the key ones are listed here on the left-hand side (Human Creativity, Problem Solving, Adaptability, Learning Modes, Self Awareness, Trust, Team hardness and Cohesion (Shared purpose)).

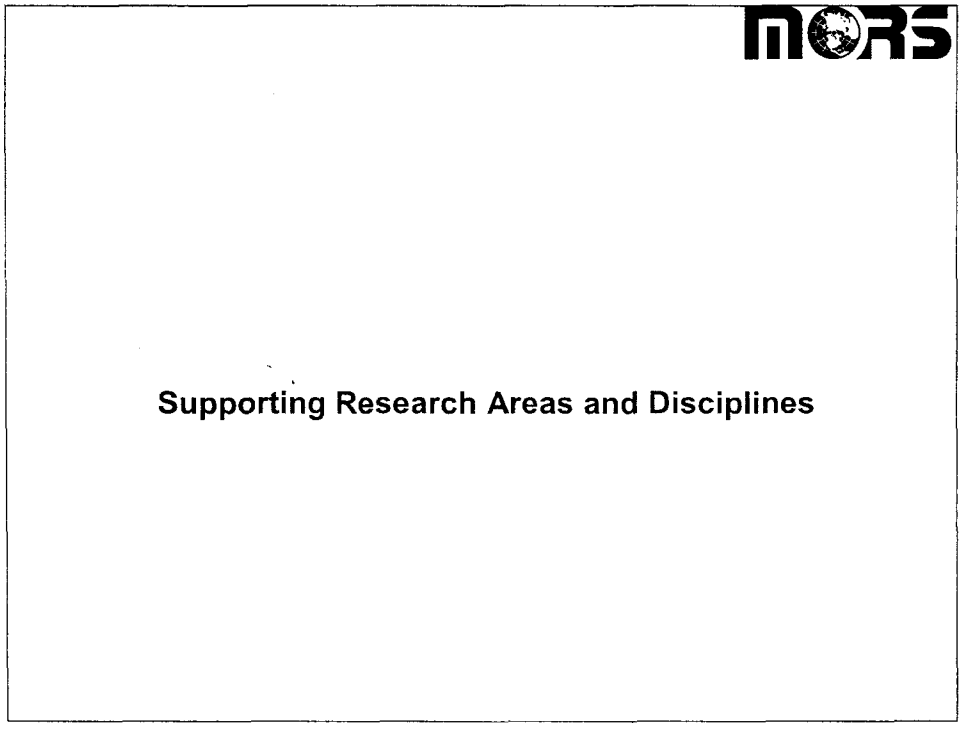
However to fully account for the cognitive and social domains, we must also take into account, in the design and training for future C2 systems, the inherent constraints that the human brings to the table (listed on the right): Memory Limitations; Pattern Mis-recognition, Decision Making and Information Processing; Lack of Co-Location; Emotion; Stress Response; and, Cognitive Fatigue.

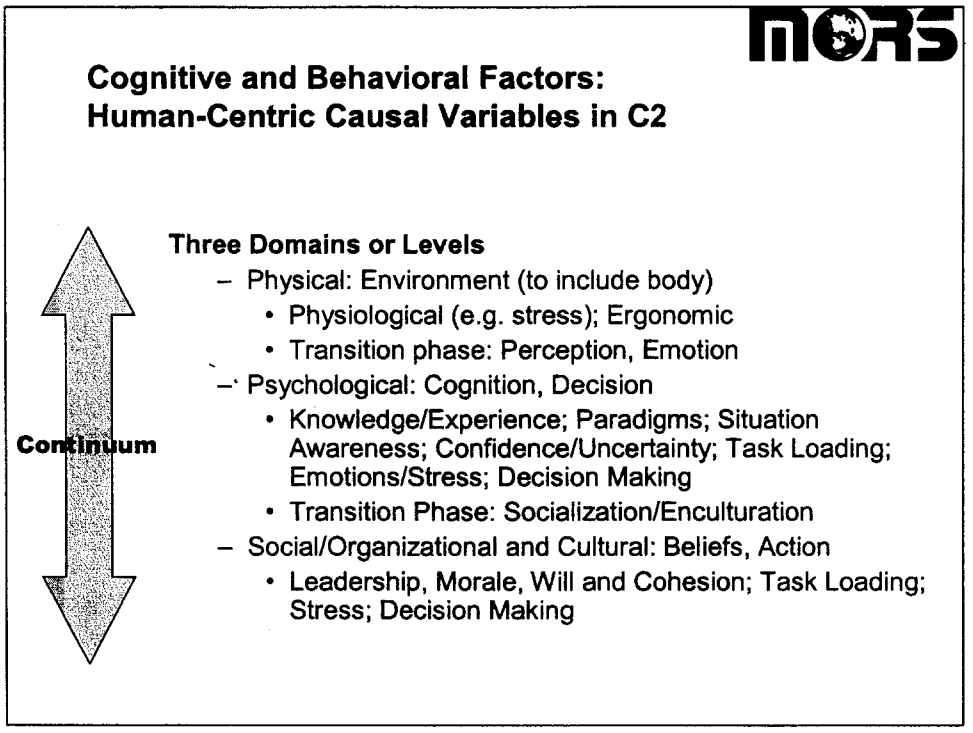
Both these enablers and constraints must be accounted to conceptualize and design C2 systems that will optimize mission performance.



Finally, these requirements for future C2 systems imply a set of key activities for C2 processes, C2 organizations, selection training, and promotion of Commanders and Staff, as well as a new philosophy for system design and acquisition that will integrate the cognitive and social domains with the better known information and physical domains. (Please see the previous slide.)

One must remember that optimizing mission performance (the ultimate MOE) requires optimizing the fit between the cognitive, social, informational, and physical domains. The cost of not doing so is too high to ignore.


MORS
Supporting Research Areas and Disciplines



WG 1 listed a large number of discrete causal variables and rank-ordered them by level of analysis (physical, individual, collective) and by extent to which they are understood within the DoD and have been incorporated into C2 systems (tools, doctrine, processes). These variables can be grouped across several domains shown here. C2 being a cyclic process, each sub-domain is interlinked via transition zones (e.g., world-perception-emotion/cognition-decision-action-world).

Each of these levels of analysis corresponds to an associable (if not yet actually associated) academic discipline. There exists a substantial body of knowledge, research and literature to address each of the relevant factors.

Relevant Discipline vs. Degree of Current Usage

	Usage
Physiological Factors	
– Physiology	Hi
– Psychology (Sensation and Perception, Emotion)	Med
– Ergonomics/Time and Motion	Hi
Cognition and Decision	
– Cognitive Psychology (descriptive)	Lo
– Decision Theory (prescriptive)	Hi
Socio-Cultural	
– Social/Organizational Psychology (teams/staffs)	Med
– Sociology	Lo
– Cultural Anthropology	Lo
– Art of War/Military History*	Med

* Added by the Synthesis Group as an important discipline

Although the entire range of social, psychological and physiological sciences are necessary for a full understanding of human factors in C2, the military's study and application of these disciplines to the C2 problem has been uneven and inconsistent.

Greatest Gaps in Current Understanding of Human Cognitive and Behavioral Factors in C2

- **Cultural Factors, Processes**
  - Beliefs and values
- **Social Factors, Processes**
  - Socialized/institutionalized behavior
    - Societal dynamics
    - Small group dynamics
    - Organizational dynamics
- **Psychological Factors, Processes**
  - Individual-level
    - Perception
    - Emotion
    - Cognition

And here is where the greatest gaps appear to remain, rank-ordered by the disparity between the required level of DoD usage and our usage heretofore.

Disciplinary Relevance and Institutional Willingness for Military Applications

	Relevance/Usage/Availability		
Physiological Factors			
– Physiology	10	7	9
– Psychology	10	5	6
– Ergonomics/Time and Motion	10	8	10
Cognition and Decision			
– Cognitive Psychology (the 'is')	10	3	8
– Decision Theory (the 'ought')	10	8	10
Socio-Cultural			
– Social/Organizational Psychology	10	6	8
– Sociology	10	2	4
– Management Science	10	6	9
– Cultural Anthropology	10	1	2
– Science of War/Military Theory	10	6	6

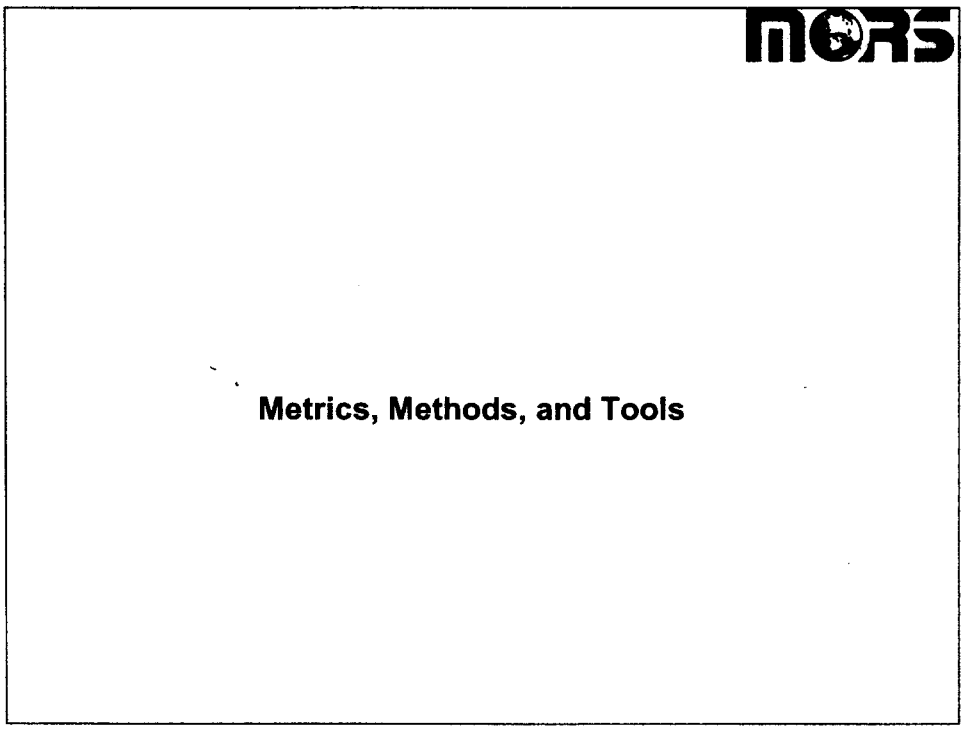
However, linking the DoD to the human scientists is itself a problem and task; the degree of availability (that is, shared beliefs, values and readiness to collaborate) between the DoD and the academy is uneven, and this effects the Return on Investment (ROI) and timing of R&D investment. In short, in some disciplines, social and attitudinal groundwork must first be undertaken (e.g., conferences, symposia, and other sponsored events/programs).

Proposed Directions for Further Research Investment

- **Maximum Immediate Payoff**
  - Psychology (Cognition, Emotion)
  - Management Science (Business, Organizational)
- **Lucrative Long-Range Payoff**
  - Sociology
  - Cultural Anthropology

Traditions of collaboration and/or readiness to collaborate make psychology and the management sciences a particularly lucrative target for high levels of immediate R&D investment. Here the ROI will be high and the risk prudent. Experimental and theoretical psychology have established a massive body of knowledge and data that the DoD and services are fairly ready to appreciate and incorporate into C2 requirements, design and doctrine, as well as in Professional Military Education (PME). The same is true concerning the burgeoning literature of the 'Revolution in Business Affairs' (RBA), much of which itself derives from the application of the human sciences to corporate needs and processes.

However, a full understanding and mastery of C2 absolutely requires a full understanding of human collective processes, and the DoD needs to make a strategic investment in the relevant research. These 'holistic' levels are, however, intrinsically less amenable to mathematical empiricism and thus have always remained susceptible to social and political ideology. Most of these attitudes have served to alienate these disciplines from the military, a sentiment that has not gone without reciprocation. As a result, long-term program planning and mutual acculturation must be undertaken at the levels of the DoD and service pedagogical establishment (NDU and the service war and command and staff colleges) and the DoD and service research sponsors/labs before extensive direct investment can yield a high ROI in the specification of requirements and design of C2 tools, processes and doctrine.


MCRS
Metrics, Methods, and Tools

Address Cognitive, Behavioral and Social Factors

- Experimentation
- Materiel development
- Training development

In order to address human cognition, behavior and social factors in our experimentation, materiel development and training development, we must first identify the appropriate experimental methods that are available to us.

A framework has been developed in the attempt to capture relevant information about the cognitive, behavioral and social factors that directly affect warfighters' performance during experimentation. In the Back Up Slides there is an example of a Data Collection and Analysis Plan (DCAP). This outline provides a good example of how an experiment approach may be developed. Materiel development (that is spiral in nature) can also use this DCAP framework as an approach for evaluating human performance as a function of the material performance. Further, training development (team and individual) that is performed in conjunction with new technologies may also benefit by this DCAP framework.

Required: Research Metrics, Methods and Tools

- Role of metrics as an integrating framework for experimentation, analysis, modeling, and assessment

When measuring human factors (to understand their impact on modeling and analysis) we should be aware of what is already out there in the scientific literature. In other words, we should do our homework and learn what has already been done and how it was done. Available research metrics, methods and tools include a large litany of approaches and utensils. For example, there are archived experiments that have researched the cognitive, social, cultural and other human factors that have a direct impact on individual and group performance. We can find such research in the FIRSTSEARCH humanities research database, among others.

For building any appropriate design for an experiment that includes the human, the researcher must consider the known constraints and address potential confounds as well as biasing variables. Several professional journals provide examples of research designs that may be used to study individual as well as group/team performance. By measuring the human cognitive, behavioral and social factors we enable modelers to create more accurate models that may in turn be used by operations research analysts.

Working Group #4 provided an excellent overview of approaches toward individual and team performance assessment and with that a subset of metric examples used for assessing cognition issues.

Example of Hypothesis statements

- **Hypothesis 1**
  - The Situational Awareness Rating Technique (SART) is a reliable measure of Situation Awareness (SA) among combat systems operators.
- **Hypothesis 2**
  - The Situational Awareness Rating Technique (SART) is a valid measure of Situation Awareness (SA) among combat systems operators.
- **Hypothesis 3**
  - Optimal system performance will positively correlate with high Situation Awareness scores.
- **Hypothesis 4**
  - Non-Optimal system performance will negatively correlate with high Situation Awareness scores.
- **Hypothesis 5**
  - Optimal system performance will negatively correlate with low Situation Awareness scores.
- **Hypothesis 6**
  - Non-Optimal system performance will positively correlate with low Situation Awareness scores.

So how do the methodologies, design paradigms and approaches to experimentation using human subjects differ from those found in the physical sciences? In order to provide valid data (or outcomes) to modeling professionals, complex methodology for designing the original experiment to study people/teams of people must be utilized. Further, there is so much variability between people and teams of people that we need more powerful statistical and analytical tools for evaluating these experimental data. This capability is facilitated by available personal computers that have increased processing power. Researchers are also fortunate enough now to be able to use the latest multivariate techniques and inferential statistics to analyze their research outcomes.

In contrast, the physical sciences are much more constant in nature and have many fixed laws. Unlike physics, for example, human behavior cannot be described in simple terms of cause and effect. Almost ALWAYS there is an interaction between several variables that contribute to a single outcome effect (or behavior, performance, etc.). Thus, psychologists must rely on complex experimental designs where one attempts to control for most of the variables that can directly or indirectly influence the behavior in question.

(Here are a few examples of hypotheses that can be found in one experiment.)

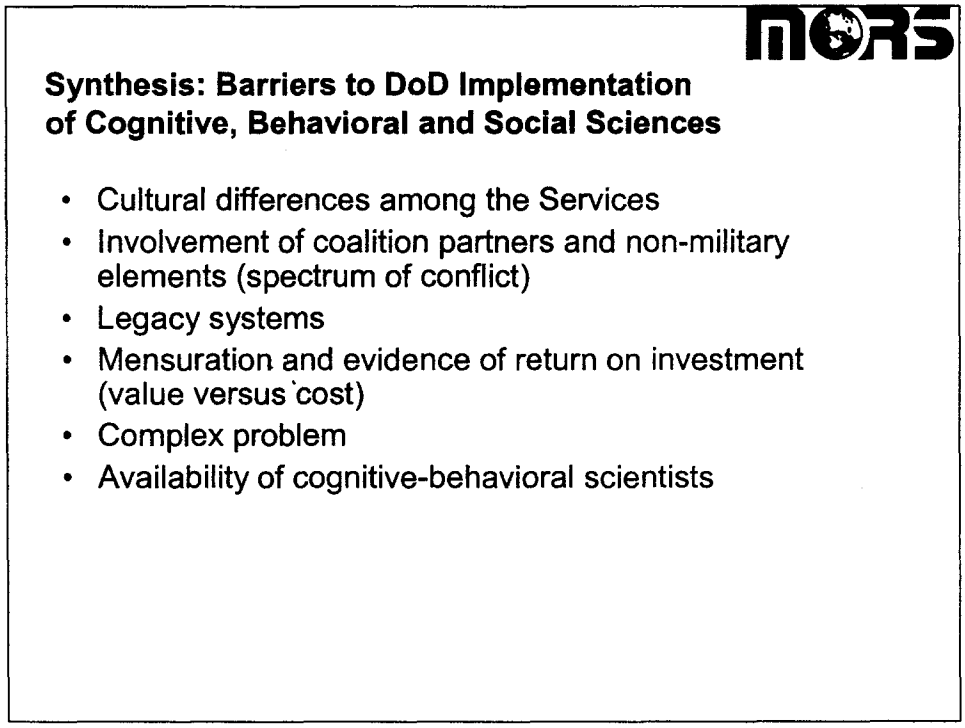
Data Scoring

There are many formal methods for determining the validity of a given scientific technique whether it is for complex software systems or the measurement of psychological constructs (Murray, 2002). To assess the validity of a given technique for collecting psychological construct data (cognitive, behavioral, social) in different contexts (lab, field) one may measure the relationship between the subjective data sets. Further, one may measure the relationship between subjective and objective data sets to infer the validity of a particular technique.

Mentioned Metrics	V&V has been established in at least one environment
Situation Awareness Global Assessment Technique	Yes
Situation Awareness Rating Technique	Yes
NASA Workload Task List	Yes

MORS

Recommended Policy, Programming, and Institutional Initiatives



The socio-cultural differences among the Services contribute to significantly different views of command and control, leading to differential views of cognitive, behavioral and social components of command and control. The socio-cultural differences need to be resolved so that a comprehensive joint (and combined) program can be instituted and managed.

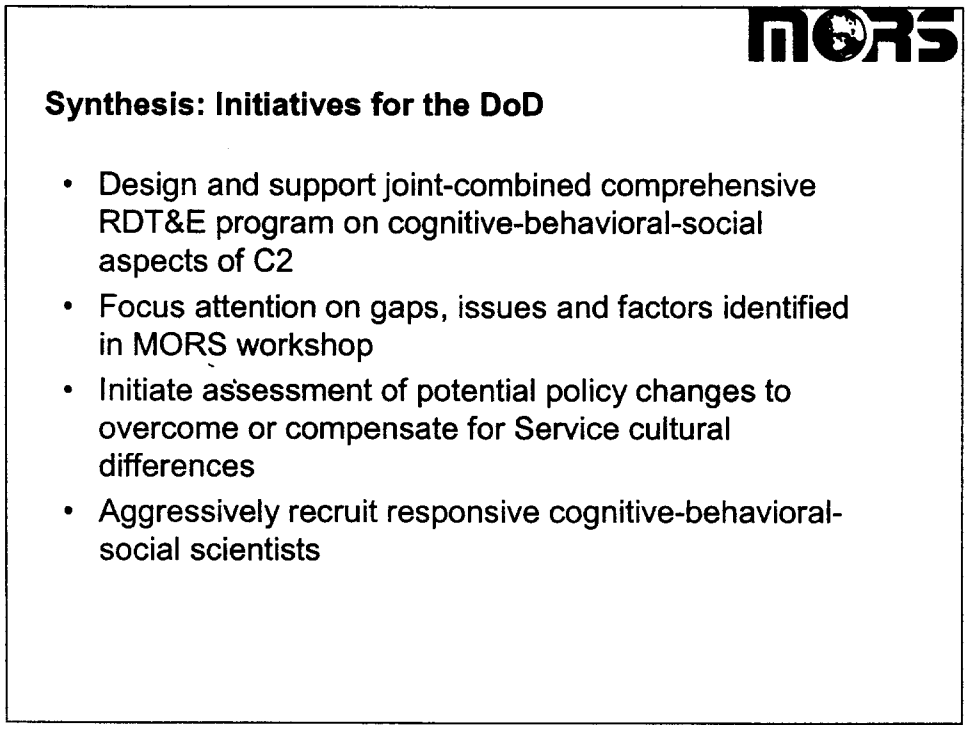
That the future will involve a wide spectrum of military operations, involving coalition partners and large numbers of non-military organizations, is widely accepted by the US DoD. It is necessary that any program dealing with the cognitive, behavioral and social components of command and control recognize and compensate for that view of the complexity of future operations.

The DoD has completed many command and control programs (developmental, experimental) without adequate consideration of cognitive, behavioral and social components. While there is considerable concern about the lack of recognition of those components, nevertheless the DoD apparently has been satisfied with its accomplishments to date. The apparent adequacy of present and planned C2 programs will be difficult to argue against.

Without valid approaches to measuring the impact of proper treatment of cognitive, behavioral and social factors it will be next to impossible to demonstrate the usefulness of such factors and substantiating a convincing return on investment to support the needed comprehensive program.

Introducing cognitive, behavioral and social factors into command and control systems design, development, test, acquisition, deployment, and employment is a complex process and will require ingenuity, perseverance, and considerable high-level support in the DoD.

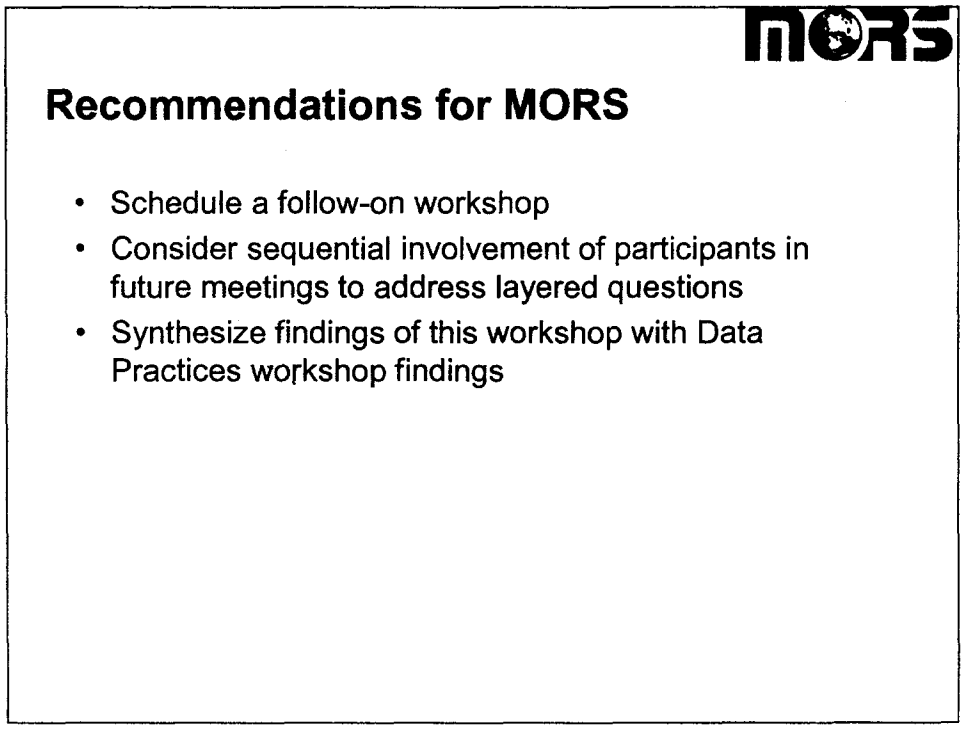
The issue of the availability of competent and appropriate cognitive, behavioral and cultural scientists and their willingness to participate in the comprehensive DoD program needs to be determined.



Using the output of the MORS workshop, the DoD should think about designing and implementing a comprehensive program to introduce relevant cognitive, behavioral and social components into command and control systems. Given the accepted fact that most, if not all, future operations, across a wide spectrum of classes of military operations will be joint and many will be combined (with participants from coalition and non-military organizations) necessitates that the program be joint and combined, with involvement (or at least recognition of) the non-military organizations' needs and competencies. It will be valuable and efficient for the Dod to identify and authorize a lead agency to coordinate the comprehensive program.

In parallel with the development of the comprehensive program, the DoD should initiate an assessment of the impact of the psyche-cultural differences among the services. Since the disparate services will have to operate together with the command and control systems and processes of the future, it may be necessary to institute policy changes to insure smooth joint functioning.

There have been indications that the community of cognitive-behavioral-social scientists is reluctant to participate in military programs. It is necessary that the matter be examined to determine its validity. If the observation is correct, the DoD needs to identify ways to overcome the reluctance. In any case, aggressive recruitment of such scientists to support the comprehensive program needs to start immediately.



Finally, the group made a number of recommendations for MORS. First, it is recommended that a follow-on meeting be scheduled to address this same set of issues in more depth. This meeting would be guided by a more refined set of questions, based on the insights developed from this Mini-Symposium.

Second, it is recommended that MORS give consideration to holding a sequential meeting of working groups, rather than parallel. The reason for this is that many of these questions are better addressed prior to others. The format of holding parallel working groups results in less than efficient use of participant time.

Thus, it is recommended that consideration be given to synthesizing the findings of this workshop with those of the MORS workshop on "Improving Defense Analysis Through Better Data Practices," held 25-27 March 2003.

Back Up Slides

Data Collection and Analysis Plan Guideline (DCAP)

Code of best practices, CCRP, Gartska, Hayes, Leedom, & Kirzl, (2002)

Introduction

Concept description (What - general)

Initiative (What - specific)

- Description
- Value of initiative on development of concept (Why)
- Experimental learning objectives

Analytical approach (This is a breakdown of the learning objectives/analytical questions and the metrics (MOEs/MOPs) that answer the questions. The analytical approach, data and other items necessary to assess each metric will also be addressed.)

Objective

- Sub-objective
  - Analytical question
    - Metrics/MOEs/MOPs
    - Methodology
    - Data required
    - MSELS required
    - Other requirements (OSDs, baseline data, models, etc.)

Experiment design details

- Experiment overview (who, what, when, where, how)
- Experimental conditions
  - CONOPS/TTP
  - Known variables
  - Known constraints
  - Interrelationships
  - Required operational assets and systems
  - Showstoppers
- Data collection plan
  - Data content (type, periodicity, format, location, timeframe, method)
  - Data collection personnel (location, timeframe, billeting, and embarkation requirements)
  - Collection equipment
  - External collection requirements

Data Collection and Analysis Plan Guideline (DCAP) cont'd.

Example of analytical approach and its components

Objective
- Sub-objective 1
  - Analytical question 1
    - Metric A
      - Methodology
      - Data required
      - MSELS required
      - Other requirements (OSDs, baseline data, models, etc.)
    - Metric B
      - Methodology
      - Data required
      - MSELS required
      - Other requirements (OSDs, baseline data, models, etc.)
- Sub-objective 2
  - Analytical question 2
    - Metric C
      - Methodology
      - Data required
      - MSELS required
      - Other requirements (OSDs, baseline data, models, etc.)
    - Metric D
      - Methodology
      - Data required
      - MSELS required
      - Other requirements (OSDs, baseline data, models, etc.)
  - Analytical question 3
    - Metric E
      - Methodology
      - Data required
      - MSELS required
      - Other requirements (OSDs, baseline data, models, etc.)
    - Metric F
      - Methodology
      - Data required
      - MSELS required
      - Other requirements (OSDs, baseline data, models, etc.)

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Acronyms

MORS Workshop: How Cognitive and Behavioral Factors Influence Command and Control

AFOTEC	Air Force Operational Test and Evaluation Center
A2C2	Adaptive Architecture for Command and Control
AFSAA	Air Force Studies and Analyses Agency
AI	Artificial Intelligence
ARI	US Army Research Institute
ARL	US Army Research Laboratory
BDA	Battle Damage Assessment
C2	Command and Control
COA	Course of Action
COMOPTEVFOR	Commander, Operational Test and Evaluation Force
COP	Common Operational Picture
DCAP	Data Collection Analysis Plan
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
EBO	Effects-Based Operations
EBR	Evidence Based Research
EMP	Electro Magnetic Pulse
FCS	Future Combat Systems
FFRDC	Federally Funded Research and Development Center
HF	Human Factors
HITL	Human-In-The-Loop
IDA	Institute for Defense Analyses
IPB	Intelligence Preparation of the Battlefield
IPT	Integrated Process Team
JHU/APL	Johns Hopkins University Applied Physics Lab
JIM	Joint/Interagency/Multinational
JTCG/HE	Joint Technical Coordinating Group
JTF	Joint Task Force
M&S	Modeling and Simulation
MOP	Measures of Performance
NAVAIR	Naval Air Systems Command
NCW	Naval Coastal Warfare
NDU	National Defense University
NGO	Non-Governmental Agency
NSC	National Security Council
NSMRL	Naval Submarine Medical Research Laboratory
NUWC	Naval Undersea Warfare Center
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OOTW	Operations Other Than War
OPTEMPO	Operational Tempo
ORD	Operational Requirements Document

ORSA	Operations Research and System Analysis
OSD	Office of the Secretary of Defense
OT&E	Operational Test and Evaluation
PME	Professional Military Education
R&D	Research and Development
RBA	Revolution in Business Affairs
RDT&E	Research, Development, Test and Evaluation
RFP	Request For Proposal
ROE	Rules of Engagement
ROI	Return on Investment
SA	Situation (or Situational) Awareness
SAGAT	Situational Awareness Global Assessment Technique
SART	Situational Awareness Rating Technique
SME	Subject Matter Experts
SOF	Special Operating Forces
T&E	Test and Evaluation
TTP	Tactics, Techniques and Procedures
US	United States
USA	United States Army
USAF	United States Air Force
USN	United States Navy
V&V	Verification and Validation
VTC	Video Tele-Conference

TERMS OF REFERENCE
MILITARY OPERATIONS RESEARCH SOCIETY (MORS)
COMMAND AND CONTROL MINI-SYMPOSIUM AND WORKSHOP
How Cognitive and Behavioral Factors Influence Command and Control

28-30 October 2003
The Institute for Defense Analyses
Alexandria, Virginia

Background

The traditional view of Command and Control in the Department of Defense (DoD) tends to focus on the technologies used to support these functions. This perspective generally views technology as rational, beneficial, and progressive. Unfortunately, this pro-technology bias may not allow us to fully consider the effects of other systemic forces, and may limit our candid assessment of new technologies.

An alternative perspective examines the influences and interactions among (1) the organization structure, (2) its people, (3) tasks, and (4) technology. Each of these factors is perceived as an integral and equally important element in the system. Technology is no longer the central focus, but one of several factors that must be considered.

In his article for the June 2002 issue of *PHALANX*, Mr. Vince Roske, FS, observed that we have traditionally viewed command and control as capable of being defined and controlled. However, human factors introduce a complex, adaptive set of behaviors and responses into command and control, and our analytical approaches are not conducive to solving such problems. Mr. Roske stated that we need to better understand how human factors influence the behavior of command and control systems. He opined that we need analytical methods to study and measure systemic factors. Rather than artificially defining a system to facilitate the analytical process, we need to develop new skills to recognize the relevant components of a system, observe rather than predict emergent behaviors, and effectively evaluate what we have observed to improve decision making.

This challenge is particularly evident in the context of new concepts of operation that strive to achieve increased information sharing, shared awareness, and collaboration. These goals are based on the assumption, however, that individuals perceive shared information in the same way. In reality, individuals have different perceptions that are based on their unique backgrounds and experiences. These differences result in a lack of common understanding and varying awareness of the situation that reflects each individual's perceptions about the information. Shared awareness is limited by the filters with which each individual perceives and interprets information. Concepts of operation that emphasize information sharing, shared awareness, and collaboration fail to recognize these limitations, creating false expectations about the efficacy of the technologies that are being designed to support these functions. Hence, there is a need to co-evolve new technologies with processes and training that recognize and accommodate human factors.

This special meeting will employ the alternative perspective outlined above to examine the influences and interactions of people, specifically human factors, on command and control structures, tasks, processes, and technologies.

Cognitive and behavioral factors will be the specific human factors that will be addressed by this special meeting. Cognitive factors refer to how people think, and include how a person relates to the environment, acquires information, and makes decisions. Behavioral factors refer to how people act, and are based on a person's beliefs, attitudes, and intentions. **The workshop will consider technological issues only as they pertain to cognitive and behavioral factors.**

Target Audience

To provide a useful, informative forum, this special meeting must acknowledge the relative lack of understanding within the Operations Research and Systems Analysis (ORSA) community regarding the role of social science in our theory and practice. Although Operations Research (OR) was originally intended to be an interdisciplinary field, it has largely evolved to address the physical sciences. The intended audience of the meeting will include social scientists, warfighters who use command and control, and the ORSA community. Social scientists will play a key role in guiding the other participants to a better understanding of the subject area and its challenges.

Format

The special meeting will be presented as a mini-symposium for the general audience, followed by a workshop for selected participants. Presentations will be limited to the mini-symposium so that working group sessions are devoted entirely to discovery, discussion, and product development.

Objectives

The mini-symposium will acknowledge the importance of the social sciences in the study and practice of OR. It will provide a forum in which social scientists can inform and educate ORSAs about cognitive and behavioral science, and how these fields directly influence our theory and practice of command and control. Specifically, social science speakers will provide a fundamental level of instruction on these topics to enlighten the ORSA community about human performance and other human issues as they relate to command and control.

The workshop will allow social scientists and ORSAs to build upon the common understanding developed during the mini-symposium to collaboratively identify areas in which improvements must be made in the theory and practice of OR relative to human performance, other human issues, and command and control.

A read-ahead package will be provided to registered participants prior to the meeting to provide an initial foundation of background material that should be of interest to the participants. All prospective participants are encouraged to explore these resources prior to the mini-symposium so that they can contribute most significantly to the accomplishment of the meeting objectives.

Working Groups and Synthesis Group

The workshop structure will consist of four Working Groups and a Synthesis Group.

Objectives

Working Group 1 - Factors

WG1.1 - What cognitive and behavioral factors are currently recognized in command and control? Edit and expand upon the factors identified in the read-ahead package.

WG1.2 - How are these factors incorporated in command and control (1) structures, (2) tasks, (3) processes, and (4) technologies?

WG1.3 - How well do current models reflect these factors and their various influences on command and control?

Working Group 2 – Future

WG2.1 - When planning for future command and control systems, how should system requirements be written to include the effects of cognitive and behavioral factors on command and control processes?

WG2.2 - What are some of the ramifications of cognitive and behavioral factors on future command and control systems?

Working Group 3 - Implementation

WG3.1 - Given that social scientists have knowledge about the potential impact of a given cognitive or behavioral factor, how can this knowledge be implemented in command and control processes, technologies, and training?

WG3.2 - What barriers currently exist in implementing such knowledge? What impact do time and resource constraints have on our ability to consider and include cognitive and behavioral factors? Are these barriers the result of gaps in research and development? How can those barriers be overcome?

WG3.3 - Produce a generic guide for inclusion in the workshop exposition that describes cognitive and behavioral requirements, issues, and capabilities that should be considered when contracting for, and developing, command and control processes and technologies.

Working Group 4 - Methods

WG4.1 - Identify methods that can be used to study and measure the influence of cognitive and behavioral factors on command and control structures, tasks, processes, and technologies.

WG4.2 - What is the status of current methods? What are the attributes and limitations of those methods?

Synthesis Group

Provide a mechanism to ensure cross-fertilization of ideas among the working groups, and to integrate and synthesize ideas from the workshop.

Members of the Synthesis Group will participate in the Working Groups as a means of facilitating conceptual synthesis and integration.

Organization Structure

Two Co-Chairs and a Recorder will lead each Working Group. The Working Group Co-Chairs are responsible for organizing and leading the working group. They will moderate the discussions and participate in the workshop synthesis session on the morning of the fourth day. Working Group Co-Chairs, in coordination with the Workshop Chair, may recruit specific individuals to be part of their working group to ensure that the requisite expertise exists in the group.

Working Group Recorders are responsible for recording the discussion of their respective working groups, noting particularly the lessons learned, issues, concerns, and recommendations of the participants. Working Group Recorders are invited to attend the workshop synthesis session on the morning of the fourth day.

The Working Group Co-Chairs and Working Group Recorders will be made aware of the meeting schedule and report deadline. Each will be asked to acknowledge that he or she will be able to support these requirements as a condition of serving in a workshop leadership position. In the event that a Working Group Co-Chair or Working Group Recorder is unable to fulfill his or her duties, that individual will be expected to help the Workshop Chair identify a suitable and available substitute.

The Synthesis Group will also be led by two Co-Chairs and a Recorder. All members of the Synthesis Group will take responsibility for participating in the workshop synthesis session on the morning of the fourth day. The Synthesis Group Co-Chairs and Synthesis Group Recorder will be made aware of the meeting schedule and report deadline. Each will be asked to acknowledge that he or she will be able to support these requirements as a condition of serving in a workshop leadership position. In the event that a Synthesis Group Co-Chair or Synthesis

Group Recorder is unable to fulfill his or her duties, that individual will be expected to help the Workshop Chair identify a suitable and available substitute.

Assignments

Working Group 1
- Co-Chair Dr. Alan Zimm, JHUAPL
- Co-Chair LT Alex Hoover, COMOPTEVFOR
- Recorder Mr. Brian Widdowson, MITRE

Working Group 2
- Co-Chair Dr. Kim Holloman, EBR
- Co-Chair Mr. Dave Garvey, Alidade, Inc.
- Recorder Ms. Tina Brown, MITRE

Working Group 3
- Co-Chair LT Katie Shobe, USN, NSMRL
- Co-Chair Dr. Barbara Black, ARI
- Recorder Mr. Dan McConnell, MITRE

Working Group 4
- Co-Chair Dr. Lyn Canham, AFOTEC
- Co-Chair Dr. Gwen Campbell, NAVAIR
- Recorder 1stLt Lindsey Schmidt, USAF, AFOTEC

Synthesis Group
- Co-Chair Dr. Dennis Leedom, EBR
- Co-Chair Dr. Lynee Murray, NUWC Newport
- Recorder Ms. Sharon Nichols, AFSAA

Agenda

Mini-Symposium - Day 1

The Workshop Chair will welcome the mini-symposium participants and provide a short introduction and overview of the subject area. This overview will include a summary of the workshop's objectives, the agenda, and leading issues pertaining to the workshop topic.

Following the Workshop Chair's comments, a plenary session will be held to describe cognitive and behavioral factors and provide the participants with a fundamental understanding of human cognition, behavior, and leading theories and models. The importance of understanding human factors as they relate to command and control structures, tasks, processes, and technologies will be addressed.

The mini-symposium will conclude with a mixer during the late afternoon.

Workshop - Day 2

The workshop will begin on the morning of the second day. The workshop participants will break into their assigned working groups to focus on the specific issue areas indicated above. A member of the Synthesis Group will be assigned to each Working Group to facilitate idea flow across the working groups.

On the afternoon of the second day, each Working Group will outbrief a summary of their key discussion points, issues, conclusions, and recommendations.

Workshop - Day 3

The working groups will re-form on the morning of the third day to refine and modify their ideas in light of the outbriefs of the other working groups. Each Working Group will provide a final outbrief on the afternoon of the third day. This session will conclude with a short summary of the issues, concerns, and recommendations identified by the workshop participants. This summary will be presented by the Synthesis Group.

Day 4 morning

The Working Group Co-Chairs will meet with the Synthesis Group on the morning of the fourth day to finalize the draft of the workshop report.

Products

The product of the mini-symposium will be a broader understanding among the participants of the role that cognitive and behavioral factors play in influencing command and control structures, tasks, processes, and technologies.

The products of the workshop will be a meeting summary and a written exposition that will identify areas in which improvements must be made in the theory and practice of OR relative to human performance, other human issues, and command and control. The exposition will include a generic guide that describes cognitive and behavioral requirements, issues, and capabilities that should be considered when contracting for, and developing, command and control processes and technologies. The exposition will be published as a section in the Analyst's Handbook.

The workshop products will be produced by the following actions:

1. Each pair of Working Group Co-Chairs, in conjunction with their Working Group Recorder, will produce a short summary document for their working group. This document will include the following items and will be submitted **prior to departure** on the third day.
    a. Purpose of the working group
    b. Membership of the working group
    c. Annotated Outbrief Templates
    d. Smooth copies of all visual materials, in both hard and soft copy, with annotations

2. **Prior to departure** on the fourth day, the Synthesis Group, in conjunction with the Workshop Chair, will review and integrate the working group reports. They will draft a meeting summary and an integrated list of issues, concerns, and recommendations.

The Workshop Chair will submit the meeting summary to the MORS office no later than 60 days after the meeting ends. That report will draw upon the materials described above. The written exposition will be submitted by the Workshop Chair to the MORS office within 150 days of the workshop. Material contained in the meeting summary and the written exposition will be used to develop one or more articles about the meeting, suitable for publication in the PHALANX and other appropriate professional journals. The Workshop Chair will prepare a briefing package for presentation to the MORS Sponsors and at the next Symposium.

Meeting Proponents

Dr. David S. Alberts, Director, Research and Strategic Planning, OASD(C3I)

Organizing Committee

Workshop Chair - Dr. Priscilla A. Glasow, 703-883-6931, pglasow@mitre.org
Dr. Jock Grynovicki, 410-278-5956, jgrynovi@arl.army.mil
Dr. John Warner, 520-538-4704, john.warner@hua.army.mil
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MORS Staff - Ms. Natalie Kelly, 703-933-9070, morsvpa@aol.com

MORS Staff - Mr. Brian Engler, 703-933-9070, evpmors@aol.com

Attendance

Attendance will be by specific invitation. The meeting will be unclassified and will be open to both U.S. and international participants. Those invited will be selected from those who have completed a request for participation in the workshop. Priority for participation in the workshop portion of this special meeting will be given to those who have proven knowledge and experience in the cognitive and behavioral fields, related social science disciplines, or the application of cognitive and behavioral theory to command and control. Priority for participation with also be allotted to warfighters who use command and control and can provide valuable first-hand insights into the subject area. Active use will be made of members of appropriate MORS working groups and of contacts with leaders in the cognitive, behavioral, and command and control communities to ensure that participants in the workshop have the expertise necessary to meet the workshop's objectives.

Schedule and Fees

The meeting will be held 28-30 October 2003 at the Institute for Defense Analyses in Alexandria, Virginia. The meeting will be held in Room 1301, with Rooms 1307, 1309, 1311, and 1313 available for working groups and the synthesis group.

> The fee for participation in the mini-symposium will be $105.00 for federal government employees and $210.00 for all others.
>
> The fee for participation in the mini-symposium and workshop will be $210.00 for federal government employees and $420.00 for all others.

The MORS office will handle all registration and logistics. They can be reached at 703-933-9070 or at morsoffice@aol.com.

How Cognitive and Behavioral Factors Influence Command and Control

Final Report

28-30 October 2003
The Institute for Defense Analyses
Alexandria, Virginia

This briefing presents the final workshop report for the MORS Command and Control workshop held in October 2003. This workshop examined how cognitive and behavioral factors influence command and control.

This workshop theme was a continuation of previous MORS fora that considered a broader, more interdisciplinary perspective of operations research analysis and its practice within the DoD.

It was intended that this workshop be the first in a series of MORS special meetings focused on cognitive, behavioral, and social factors. As such, the focus of this workshop was primarily on discovery and discussion, rather than the generation of recommendations. An effort was made, however, to identify some early ideas that might serve as starting points for subsequent workshops and future recommendations.

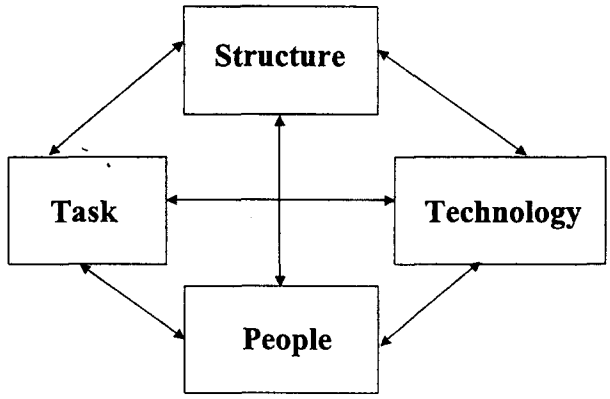
Background

- The traditional view of Command and Control (C2) within the DoD tends to view technology as rational, beneficial, and progressive.
- This pro-technology bias may limit our candid assessment of new technologies.
- An alternative perspective considers the influences and interactions among several factors, as illustrated in the following slide.

This mini-symposium and workshop was motivated by the concern that the DoD has too often viewed command and control narrowly in terms of technology, particularly information and communication systems.

The premise for this workshop was to use an alternative holistic perspective that allowed the examination of command and control in terms of the influences and interactions of several factors, shown on the next slide.

Leavitt's Diamond



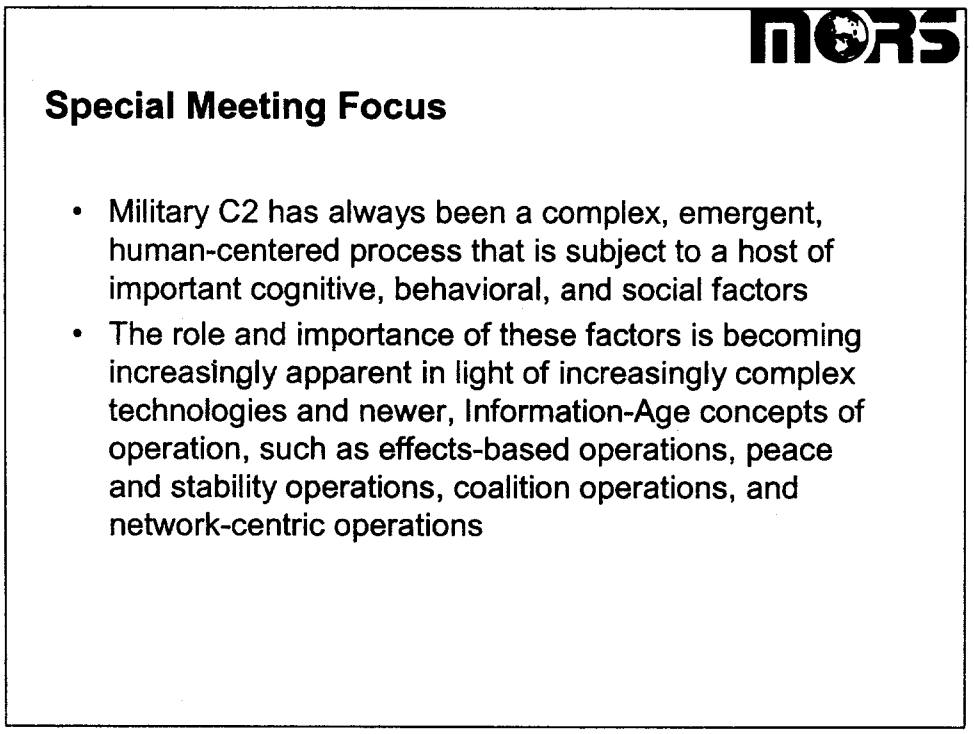
Leavitt, H. J. (1965). Allied organizational change in industry: Structural, technological and humanistic approaches. In J. G. March (Ed.), Handbook of Organizations (pp. 1144-1170). Chicago: Rand McNally.

These several factors are illustrated by Leavitt's Diamond, which comes from the organizational behavior literature of 1965.

In this conceptual model, each of the factors is perceived as an integral and EQUALLY IMPORTANT element in the system.

Technology is no longer the central focus, but one of several factors that must be considered.

The workshop was carefully focused to examine the influences and interactions of people, specifically their cognitive and behavioral factors, on command and control structures, tasks, processes, and technologies.



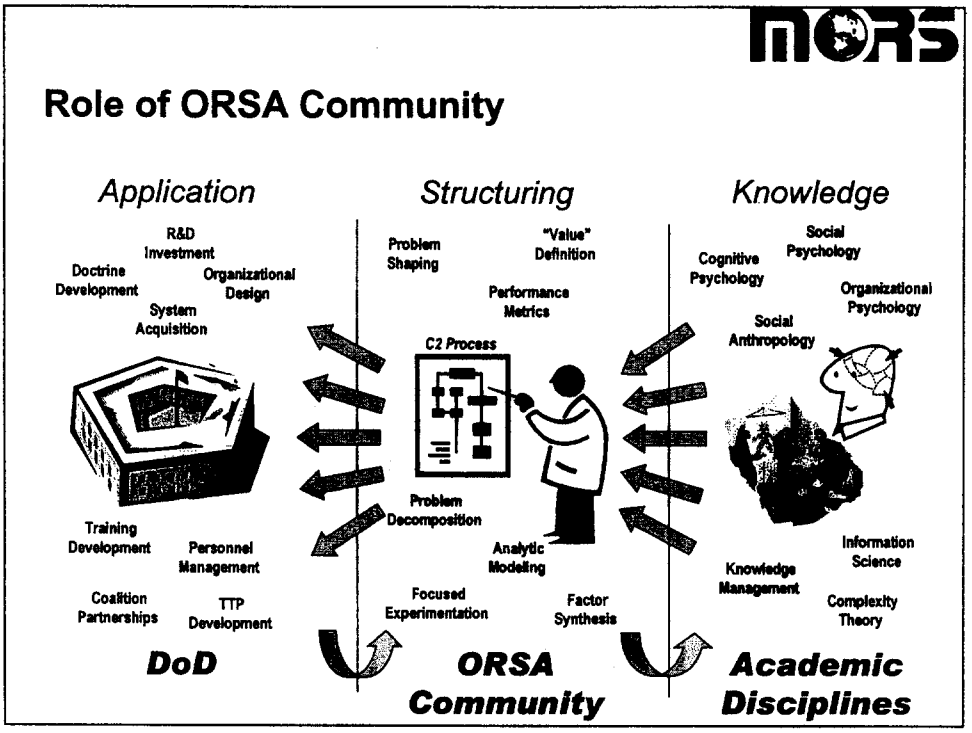
In particular, the meeting focus recognized that command and control is a complex, emergent, human-centered process that is subject to a host of cognitive, behavioral, and social factors.

Throughout the meeting, emphasis was given to highlighting the role and importance of these factors vis-à-vis technology design and emerging operational concepts.

The objective of this special meeting was to provide a forum for the exchange of ideas among warfighters, social scientists, and operations research analysts.

It was envisioned that this exchange would lead to the development of a common understanding as to how various cognitive, behavioral, and social factors influence command and control structures, tasks, processes, and technologies.

Finally, it was envisioned that the meeting would establish a foundation for identifying how these factors might be incorporated in future command and control concepts and systems.



This slide was developed by the Synthesis Group and aptly illustrates the relationships among warfighters, the OR community, and key academic disciplines, including the social and behavioral sciences.

Starting on the right side of the chart, we know that there are many academic disciplines and bodies of knowledge that can contribute to our understanding of command and control.

On the left side of the chart, we can identify areas within the DoD that could benefit from the application of these disciplines. What is lacking is an effective bridge between these two communities.

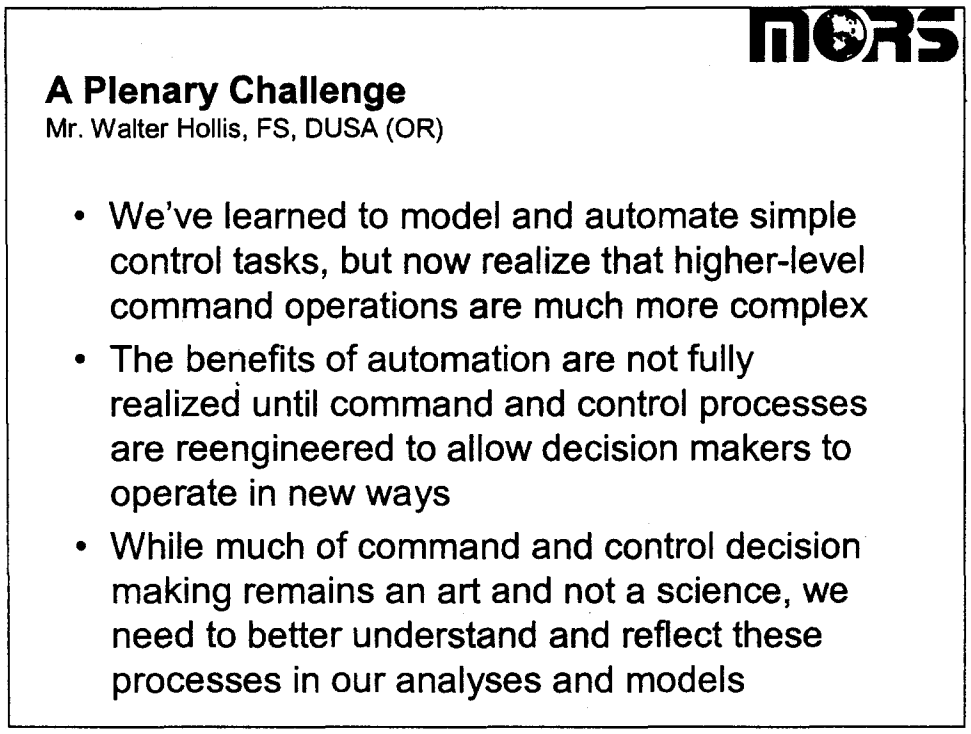
The ORSA community is ideally suited to provide that bridge. The ORSA community has the ability to structure knowledge in meaningful ways that can guide intelligent policy formulation, investment planning, and force development within the DoD.

Identifying what's important to consider in this structuring, what methods and tools are required, and what types of analytic paradigms are useful in developing this structure are all questions that were at the heart of this meeting.

Academic Disciplines that Offer Insights into Cognitive, Behavioral, and Social Factors

- Physiology
- Psychology (Sensation and Perception, Emotion)
- Ergonomics, Time and Motion
- Cognitive Psychology
- Decision Theory
- Social Psychology
- Sociology
- Organizational Theory
- Management Science
- Cultural Anthropology
- Science of War/Military Theory

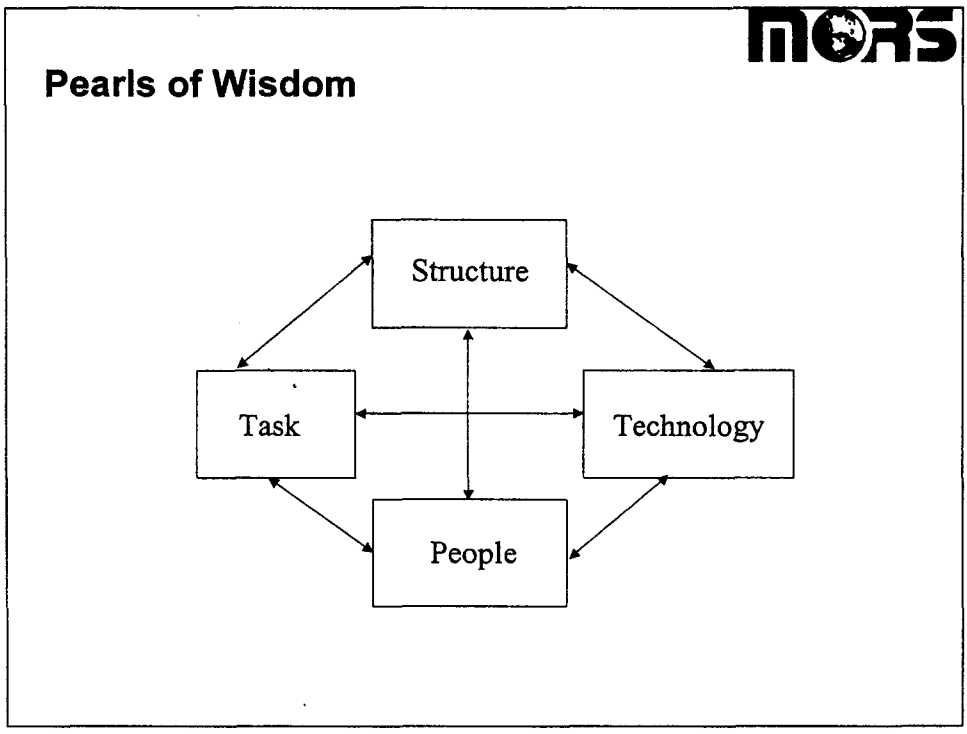
Most of the working groups drew on their knowledge of specific academic disciplines to suggest those that might have particular relevancy to greater understanding of cognitive, behavioral, and social factors.



A mini-symposium format was used on the first day of the special meeting.

Mr. Hollis, FS, not only provided the MORS Sponsor Welcome, but also served as our opening speaker.

His plenary presentation specifically challenged the participants and all operations research analysts to better understand and reflect complex command and control processes in our analyses and models.



We had several other mini-symposium speakers, as well as two tutorials, the synopses of which are contained in the Synthesis Group's report. Two of the mini-symposium speakers were widely cited during the follow-on workshop.

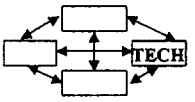
The first of these speakers was Dr. Paul Funk, LTG, USA (ret) who provided us with an Operation Desert Storm commander's perspective.

The other referenced speaker was Col Phil Exner, USMC, who lead the Marine Corps' Enduring Freedom Combat Assessment Team in Iraq.

Their comments made a distinct impression on the workshop participants, and their insights were exactly on target with what this workshop was about.

The following slides follow the format of Leavitt's Diamond and reveals some of the particularly relevant pearls of wisdom that these two warfighters gave us.

Technology Pearls



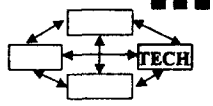
- Technology can work well, but still not contribute to battlefield performance
- Email, phone, and chat proliferate workload irrespective of the chain of command
- Increased capability may decrease effectiveness (more technology, information overload)
- Finally, concern that in network-centric warfare, everything depends on the network - What if it doesn't work?

It's important to read each of these pearls, not as prescriptive ideals, but as descriptive realities, that are based on the first-hand experiences of these two senior warfighters.

The common theme of the pearls on this slide is simply that technology may not always be the answer and indeed, may cause other problems or set up obstacles that impede mission performance.

(The first and last bullets were offered by Dr. Funk. The second and third bullets were extracted from Col Exner's presentation.)

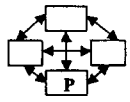
Technology Pearls (continued)



- The importance of bandwidth in OIF
  - Bandwidth was allocated to the higher echelons, primarily for political and strategic VTCs
  - Lower echelons didn't use technology – knew bandwidth wasn't available for operational and tactical needs
  - Lower echelons resorted to low tech methods and systems
  - Particularly problematic for ground forces where individual soldiers needed access
  - Failure to appreciate or quantify the cost of misallocating bandwidth to those who didn't need it for operational use
  - Seniors need to curb their appetites for bandwidth

Col Exner discussed the importance of bandwidth in Iraq.

People Pearls



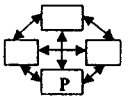
- We can no longer expect to "bend" people to technology; rather, we need to study how best to produce creativity at the nexus of people and technology
- The soldier's acceptance of new concepts and systems is essential to success
  - We need to build confidence in new ideas, and provide equipment and training that meets the soldier's needs
  - Needs are not always task related
  - Needs may be cognitive, behavioral, or social needs, such as how information is displayed, how teams operate, how tasks are shared

Dr. Funk and Col Exner also provided excellent insights about the importance of people in command and control, and their relationship to technology.

The first three bullets on the next two slides were taken from Dr. Funk's presentation. The remaining bullets were provided by Col Exner.

Again, these are not prescriptive ideals. They are realities that we need to address in our command and control structures, tasks, processes, and technologies.

People Pearls (continued)

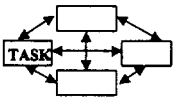


- Juniors must have trust in their equipment and receive training to use that equipment effectively
- We must recognize the importance of relationships
  - Commanders who come up the career ladder together often form personal friendships
  - When command and control systems break down, such relationships often take over
- Technical solutions cannot replace human judgment

How do we help our troops gain trust in the technologies that are provided to them?

How can we design new technologies and systems that recognize and support the user's cognitive, behavioral, and social needs?

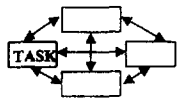
Task Pearls



- Decision making tasks
  - How much information is enough to make a decision?
  - The lower the tolerance for risk, the higher the demand for information to avoid that risk
  - Commanders manage information differently, therefore, information must be shaped for the individual commander

Col Exner addressed the task element by focusing on decision making tasks in particular.

Task Pearls (continued)



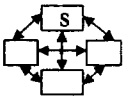
- Tasks do not always require quantifiable information
- Just because something cannot be measured or quantified, doesn't mean it isn't important
  - Qualitative methods, such as observation, have their uses as well
- Commanders must perform their tasks in a timely manner
  - Concern that they will wait for more or better information rather than act or make a decision

Dr. Funk considered how tasks might not be performed in a timely manner where the commander requires quantifiable information, more information, or better information.

The usefulness of qualitative methods, such as observation, problem structuring, and ethnography, was also noted.

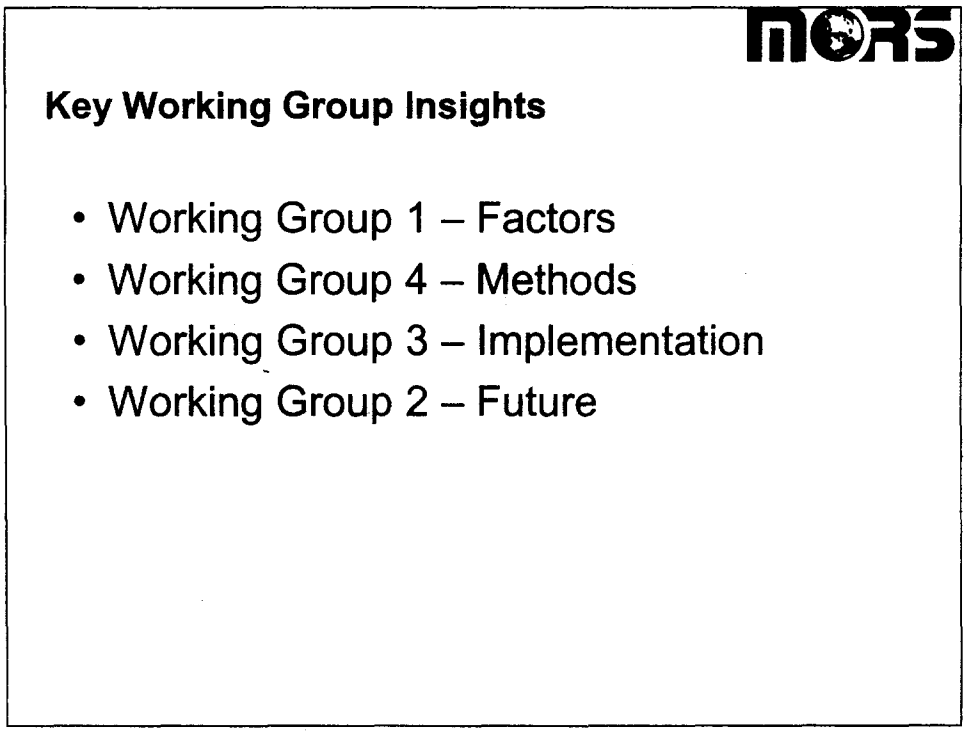
We still haven't recognized the value of incorporating these types of methods into our practice of operations research analysis.

Structure Pearls



- The importance of teams
  - Increased centralization reduces the ability of informal relationships to influence the process
  - Centralization requires the formation of new teams that have no prior history or experience working together
  - Lack of team experience requires rules and procedures that slow the process
  - Slower process does not meet OPTEMPO requirements
- Command and control becomes synched to a sequential, procedural planning mindset rather than the dynamic rhythm of the battlefield

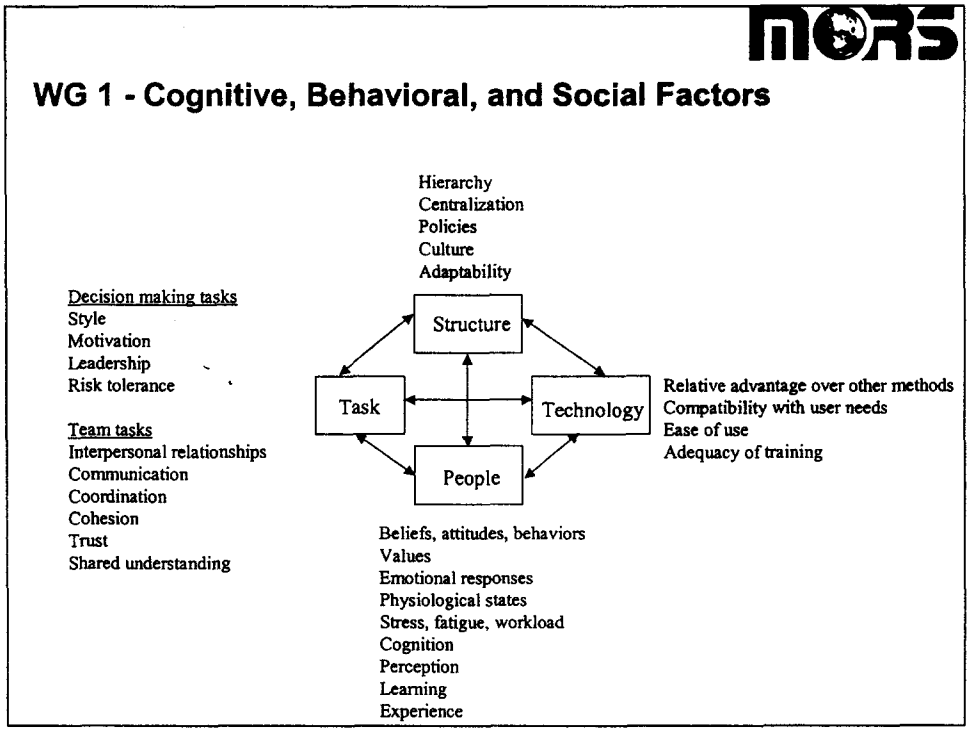
Finally, Col Exner addressed how the organization structure may affect performance by examining the role of teams and how their formation in highly centralized organizations may adversely affect mission performance.



Following the mini-symposium, the participants were divided into four working groups that addressed questions related to key factors, methods, implementation, and future requirements. Over the next two days, these groups engaged in open debate and developed various insights related to the objectives of this special meeting. Each of these working groups developed a final briefing that highlighted specific insights from their discussions. The Synthesis Group integrated these insights and developed a separate synthesis outbrief.

The following slides draw heavily on the Synthesis Group's outbrief, but also highlight some of the key findings of the individual working groups.

Rather than review the working groups' findings in numerical order, they will be addressed in logical order following the content of their findings and how each working group's findings fit with those of the other working groups.



WG 1 was responsible for identifying cognitive, behavioral, and social factors that influence command and control structures, tasks, processes, and technologies.

This graphic is based largely on that work although WG 4 also identified many of these same factors in having potentially significant impacts on mission outcomes.

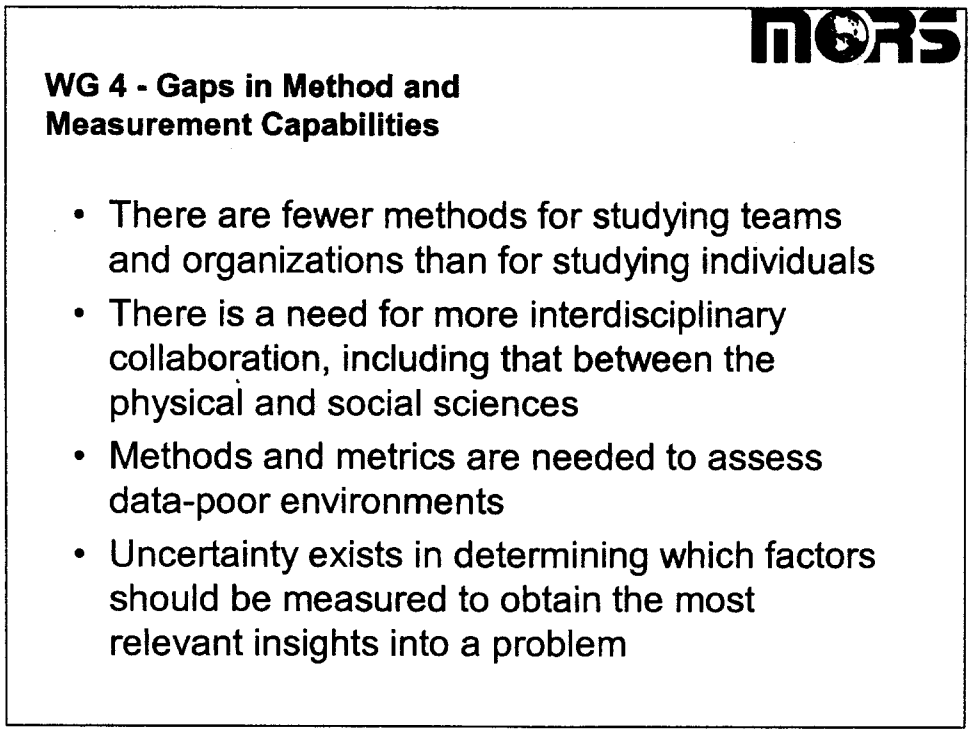
WG 2 used a similar diagram to reflect the holistic system view that they felt was important in looking toward future needs of command and control.

WG 4 - Methods for Studying and Measuring the Influence of Cognitive, Behavioral, and Social Factors on Command and Control

- Use a convergence of multiple measures for a single construct
- Shared construct definitions are critical for metric development and measurement success
- Some measurement dimensions
  - Objective versus Subjective
  - Process versus Outcome
  - Quantitative versus Qualitative

WG 4 discussed methods for studying and measuring the influence of cognitive, behavioral, and social factors on command and control.

This slide incorporates some of their observations.



WG 4 also identified some of the gaps that currently exist in our method and measurement capabilities.

WG 3 – Implementing Our Knowledge about Cognitive, Behavioral, and Social Factors

Problem	C2 process 1	C2 process 2	C2 process 3	C2 process 4		
	Info Gathering	Decn Making	Communicating	Feedback/NCW	C2 Technology	C2 Training
Cognitive Factors (Behavior/Aspects)	1) data overload	1) groupthink 2) (decision paralysis)	1) bottlencks 2) unanalyzed data	1) real time filtering	1) lack of objectives for system development 2) Bandwidth 3) no standards for non-ergonomic cognitive factors for systems design	1) how to recreate a thinking enemy
Human Performance (Behavior; individual or team)	1) Fatigue and Physical stress 2) signal detection and classification	1) fatigue/physical stress adverse effects are exacerbated 2) allowing for creativity while adhering to standards	1) language barriers 2) cohort issue 3) service culture	1) digital systems - alerts/shared knowledge 2) analog systems -manual processing 3) COA analysis and wargaming	1) need to accommodate individual differences	1) how to create a physiologically realistic friendly/ enemy situation
Command Style (Interpersonal behavior)	1) striking the balance of staff autonomy and command directed necessity 2) varying levels of micromanagement involved for subordinate action	1) striking the balance between consistency (standards) of decisions with creativity and initiative 2) influence of negative command climate	1) degradation of VTC capability 2) balance in battle preparation and communication to accommodate robust plan adjustments	1) identifying causal results attributing cognitive factors 2) capturing the logic/reasoning involved with actual decisions	1) automate capture of tagged data to subjective data 2) design specificity between staff and command requirements	1) how to compensate for absence of experienced commander 2) training criteria to establish effective command styles 3) need to represent asymmetric/foreign command styles

WG 3 developed a detailed spreadsheet that examined the problems posed to cognition, behavior, and command style by such processes as information gathering, decision making, communicating, providing feedback, technology, and training.

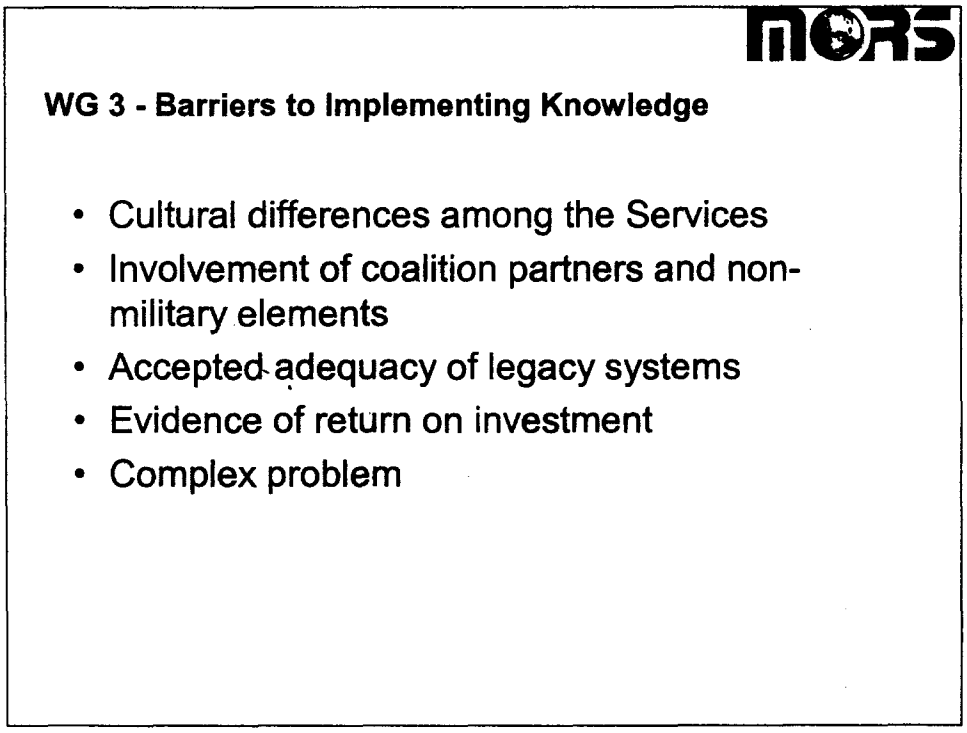
For example, information gathering can cause data overload at a cognitive level, fatigue and physiological stress at a human behavior level, and invoke problems associated with micromanagement in terms of command style.

WG 3 - Implementing Our Knowledge (continued)

Implementation	C2 process 1 Info Gathering	C2 process 2 Decision Making	C2 process 3 Communication	C2 process 4 Feedback/NCW	C2 Technology	C2 Training
Cognitive Factors (Behavior/Aspects)	1) relevance 2) filters 3) data aggregation	1) exercises 2) Trained facilitators 3) mentors	1) training in relevant service/coalition language and cultural differences	1) processes to absorb for receipt/ misunderstanding critical orders	1) include cognitive scientists in all phases of acquisition 2) use of portal technology 3) visualization technologies	1) include cognitive scientists in IPTs 2) develop performance standards
Human Performance (Behavior; individual or team)	1) using staff interactions to determine collection priorities 2) integrating performance degradation studies with doctrine		1) consolidate or centralize effort to research/ understanding implications of Reachback in various types of employment, e.g. UAV, vehicle maintenance, medical consultation, etc.	1) Joint training 2) and every NCW training exercise should assure HEMP destroys all electronics - continue to fight without NCW	1) modularity and tailorability solutions 2) early use of "HTTL" simulation in design and development, e.g. Systems Integration Labs	1) need for training SIL 2) integrating performance degradation results into simulations/other training models 3) end of every NCW training exercise should assure HEMP destroys all electronics - continue to fight without NCW 4)training differences between more modular force structure and unit replacement policy
Command Style (interpersonal behavior)	1) experimenting with situational styles to dermine guides for particular situations 2) staff training for different echelons	1) in training focus on creativity aspects of DM and capture data relating to environmental factors	1) experiment with differing Cmd styles during controlled info gaps and battle prep	1) allow cognitive scientists to participate in various operations to record selected metrics 2) gain closer access to Cmdrs pre/post activity	1) incorporate techn expertise into decision making process	1) ensure in individual, collective sequencing of training, it includes new or alternative technology approaches /capabilities 2) C2 training in command style and cultural awareness

WG 3 then developed a second spreadsheet that examined the implementation of cognitive, behavioral, and command style actions to mitigate these problems.

For example, to alleviate the problem of data overload, WG 3 recommended that the relevance of incoming data be assessed to filter or aggregate data and avoid cognitive overload. Similarly, data collection priorities could be established through staff interactions to preclude fatigue and physiological stress. Finally, experimentation with different situational styles could provide alternative responses at the command level to avoid micromanagement.

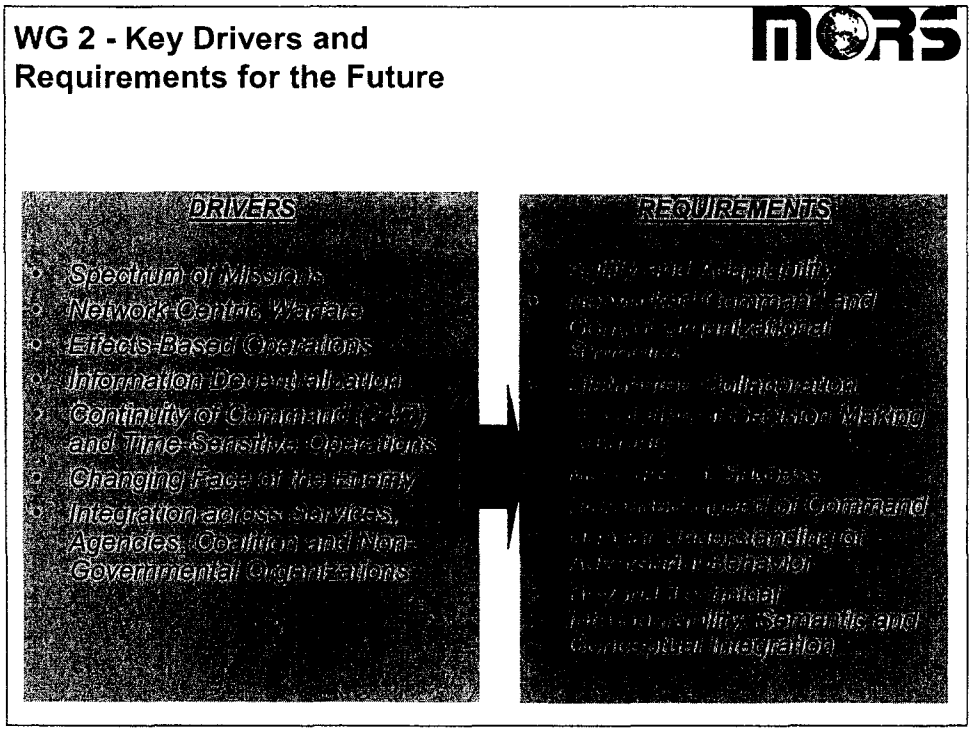


WG 3 noted that socio-cultural differences among the Services contribute to significantly different views of command and control, that lead to different views of cognitive, behavioral and social components of command and control.

It is widely accepted in the DoD that the future will involve a wide spectrum of military operations, involving coalition partners and large numbers of non-military organizations. It is necessary that any program dealing with the cognitive, behavioral and social components of command and control recognize and incorporate these complexities.

It must be noted that the DoD has already completed many command and control programs without adequate consideration of cognitive, behavioral and social components. While there is considerable concern about the lack of recognition of those components, the DoD has otherwise seemed satisfied with its accomplishments to date. The apparent adequacy of present and planned command and control programs will be difficult to argue against. Analyses are needed to demonstrate the benefits of incorporating cognitive, behavioral, and social factors into the design of command and control systems.

Finally, introducing cognitive, behavioral and social factors into the design, development, test, acquisition, and deployment of command and control systems is a complex process that will require ingenuity, perseverance, and considerable high-level support in the DoD.



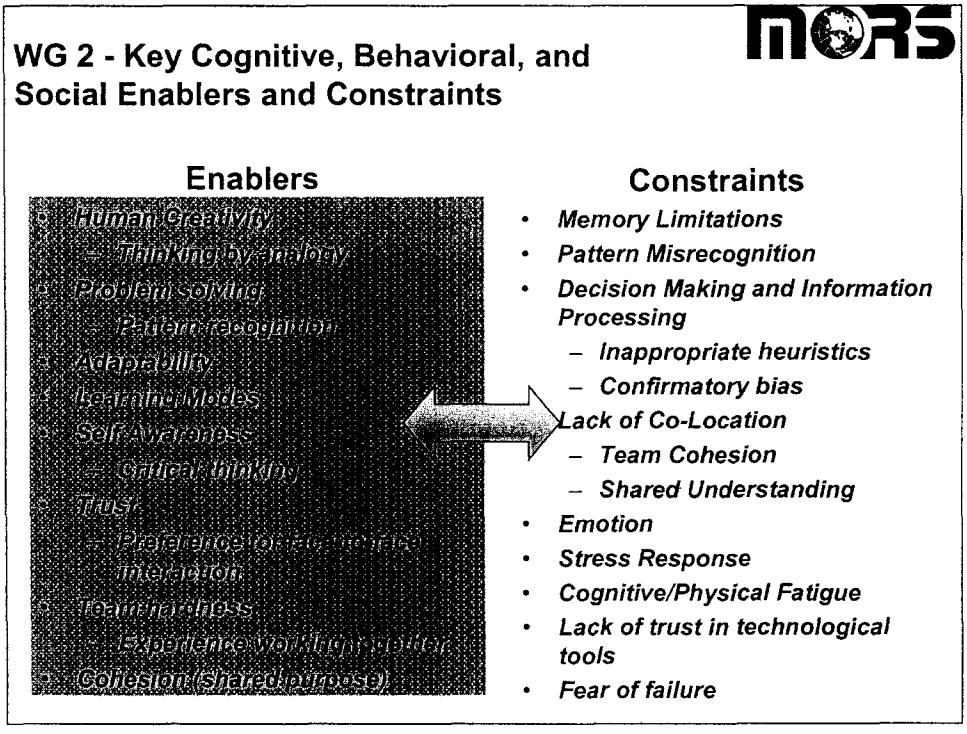
Finally, WG 2 examined the ramifications of cognitive, behavioral, and social factors on future command and control systems.

This slide resulted from their deliberations and those of the Synthesis Group in identifying the key drivers and resulting requirements for future command and control systems.

The left hand box shows the set of drivers that currently define the nature of future military operations.

In turn, these drivers call for certain cognitive, behavioral, and social requirements that are expected to characterize future missions.

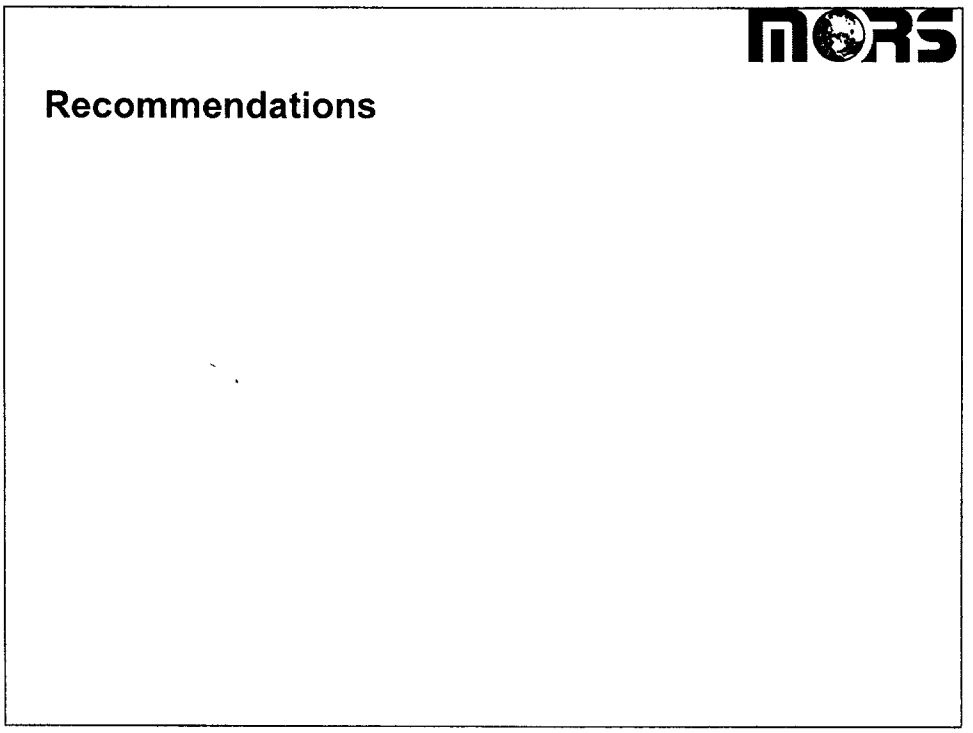
It is important to think of the requirements in terms of what they mean to the human component, rather than in terms of the mission, task, or technology.



The Synthesis Group noted that we must understand, model, measure, and develop the human enabling factors that are necessary to fulfill the requirements listed in the previous chart. Some key enablers generated by WG 2 are listed here on the left-hand side.

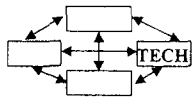
However, we must also recognize the inherent constraints that the human brings to the table, some of which are listed in the right hand box.

Both enablers and constraints must be accounted for in the conceptualization and design of future command and control structures, tasks, processes, and technologies.



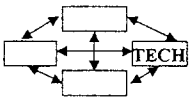
The following set of recommendations were derived from the pearls of wisdom provided by the mini-symposium speakers and from the products of the working groups and Synthesis Group.

Technology



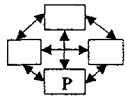
- Assess the direct contributions of new technologies on battlefield performance through studies and analyses during system acquisition and initial fielding
  - Refine or remove those technologies that adversely affect battlefield performance
- Conduct information overload studies that examine the impact of multiple, competing media (email, phone, chat, etc.) on individual and team workload and effectiveness
  - Make changes to doctrine and organization structures to employ only those media that have a positive impact on individual and team workload and effectiveness

Technology (continued)



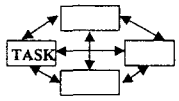
- Research network dependencies
  - Determine the optimal mix of uses for limited bandwidth and other network assets
  - Recommend system or structure redundancies to mitigate potential network failures
  - Identify alternative lines of communication and collaboration in the event that the network fails

People



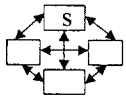
- Design and support a joint-combined comprehensive RDT&E program to examine the cognitive, behavioral, and social aspects of command and control
  - Identify cognitive, behavioral, and social needs of individuals and teams, as they relate to command and control structures, tasks, processes, and technologies
  - Conduct user acceptance studies of new structures, tasks, processes, and technologies
  - Assess the role of trust in technology; identify approaches for instilling confidence and trust
  - Explore how training programs should incorporate the user's cognitive, behavioral, and social needs
  - Understand the roles of informal relationships and their influences on command and control decisions and actions

Task



- Conduct studies to determine how much information is enough to support decision making
  - Quantity of information
  - Quality of information
  - Reliability of sources
- Design decision tools that shape information for the individual commander
- Incorporate qualitative methods in the analyst's toolkit to enhance information gathering and assessment

Structure



- Examine the role of teams in command and control
  - How do teams fit within existing organizational structures?
    - Teams vis-à-vis informal relationships
    - Team formation
    - Team roles
    - Development of team experience and trust
  - How is workload shared within a team?
  - What processes make teams effective?
  - How do teams use various technologies?

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How Cognitive and Behavioral Factors Influence Command and Control

Dr **Priscilla A. Glasow**, FS, MITRE, pglasow@mitre.org

This workshop was held 28-30 October 2003 at the Institute for Defense Analyses in Alexandria, Virginia and examined how cognitive and behavioral factors influence command and control. This theme was a continuation of previous MORS fora that considered a broader, more interdisciplinary perspective of operations research analysis and its practice within DoD. It is intended that this workshop be the first in a series of MORS special meetings focused on cognitive, behavioral and social factors. As such, the focus of this workshop was primarily on discovery and discussion, rather than the generation of recommendations. An effort was made, however, to identify some early ideas that might serve as starting points for subsequent workshops and future recommendations.

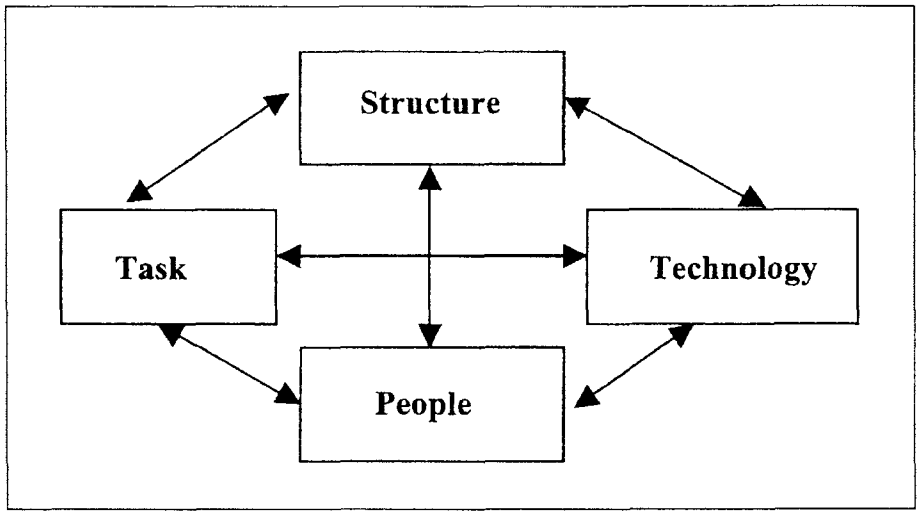

Figure 1. Leavitt, H. J. (1965). Allied organizational change in industry: Structural, technological and humanistic approaches. In J. G. March (Ed.), **Handbook of Organizations** *(pp. 1144-1170). Chicago: Rand McNally.*

Background

The traditional view of command and control in the Department of Defense (DoD) tends to focus on the technologies used to support these functions. This perspective generally views technology as rational, beneficial and progressive. Unfortunately, this pro-technology bias may not allow us to fully consider the effects of other systemic forces, and may limit our candid assessment of new technologies.

An alternative perspective examines the influences and interactions among: (1) the organization structure; (2) its people; (3) tasks; and, (4) technology. Figure 1 illustrates **Leavitt**'s Diamond, which is taken from the organizational behavior literature of 1965. In this diagram, each of these factors is perceived as an integral and *equally important* element in the system. Technology is no longer the central focus, but one of several factors that must be considered.

This special meeting employed the alternative perspective illustrated by Leavitt's Diamond to examine the influences and interactions of people, specifically human factors, on command and control structures, tasks, processes and technologies. Cognitive and behavioral factors were the specific human factors that were addressed by this special meeting. Cognitive factors refer to how people think, and include how a person relates to the environment, acquires information, and makes decisions. Behavioral factors refer to how people act, and are based on a person's beliefs, attitudes and intentions. The participants elected to add social factors to the workshop focus to more fully represent the relevant social sciences.

Target Audience

Although operations research was originally intended to be an interdisciplinary field, it has largely evolved to address the physical sciences. Hence, the audience for the meeting was specifically broadened to include senior decision makers, warfighters, social scientists and operations

(See **COMMAND AND CONTROL,** *p. 14)*

REALITY

(continued from p. 13)

past situations, and let the current decision taken by the human become another data point for future analysis. We can use the worldwide network of computers to gather information. We can use computers to help manage and track the flow of work and information. We can confine models to domains in which their predictive power can be used reliably, namely domains in which the rules are known in advance. In all cases, however, we must let the computer support the decision maker, and not let the computer make the decisions.

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Readings

Peter J. Denning. 1988. Blindness in the design of intelligent systems. *American Scientist 76,* 2 (March-April), 118-120.

Biography

***Peter J. Denning** is Chairman of the Computer Science Department at the Naval Postgraduate School in Monterey, California. He is also director of the Cebrowski Institute, a research center for information innovation and superiority. He came to NPS in 2002 from George Mason University, where he served as vice provost for continuing professional education, associate dean for computing, and chair of the Computer Science Department in the School of Information Technology and Engineering. He founded the Center for the New Engineer in 1993. He was the founding director of the Research Institute for Advanced Computer Science at the NASA Ames Research Center, was co-founder of CSNET, and was head of the computer science department at Purdue. He received a PhD from MIT and BEE from Manhattan College. He invented the working set model for program behavior and helped establish virtual memory as a permanent part of operating systems. He co-invented operational analysis, an approach to computer system performance prediction. He was president of the Association for Computing Machinery 1980-82. He chaired the ACM publications board 1992-98 where he led the development of the ACM digital library, and now chairs the ACM Education Board. He has published 7 books and 290 articles on computers, networks, and their operating systems, and is working on 3 more books. In 2002, he was named one of the top 5 best teachers at George Mason University and the best teacher in the School of Information Technology and Engineering. In 2003, he received one of Virginia's 10 outstanding faculty awards. He holds three honorary degrees, three professional society fellowships, two best-paper awards, three distinguished service awards, the ACM Outstanding Contribution Award, the ACM SIGCSE Outstanding CS Educator Award, and the prestigious ACM Karl Karlstrom Outstanding Educator Award.* ✪

COMMAND AND CONTROL

(continued from p. 1)

research analysts. Social scientists played a key role in guiding the other participants to a better understanding of the subject area and its challenges.

Over 80 US and international participants attended. All of the Military Services, the Joint Staff, and the Office of the Secretary of Defense were represented, as well as several Federally-Funded Research and Development Centers (FFRDC) and a broad cross-section of industry and academia.

Mini-Symposium

Objectives

The mini-symposium provided a forum for developing an increased awareness and appreciation of cognitive, behavioral and social science factors within the military operations research analysis community. The Synthesis Group developed Figure 2 to illustrate how the social sciences fit within DoD and the military operations research community.

Speakers

The plenary challenge was presented by Mr **Walt Hollis**, FS, Deputy Undersecretary of the Army for Operations Research. Mr Hollis noted that we have learned to model and automate simple control tasks, but now realize that higher-level command operations are much more complex. He further stated that the benefits of automation are not fully realized until command and control processes are reengineered to allow decision makers to operate in new ways. Mr Hollis concluded that, while much of command and control decision making remains an art and not a science, we need to better understand and reflect these processes in our analyses and models.

Although the Synthesis Group's report summarizes the presentations of the mini-symposium speakers and tutorials, two speakers had a distinct impact on the workshop portion of the special meeting. The first of these speakers was Dr **Paul Funk**, LTG, USA (Ret.) who provided us with an Operation Desert Storm commander's perspective. The other referenced speaker was Col **Phil Exner**, USMC, who led the Marine Corps' Enduring Freedom Combat Assessment Team in Iraq. Many "pearls of wisdom" were extracted from these pre-

sentations that were later widely cited during the workshop and are used here as a common foundation for this article. These pearls have been grouped according to Leavitt's Diamond diagram. They are not prescriptive ideals, but descriptive realities, that need to be addressed by our command and control structures, tasks, processes and technologies.

Technology Pearls of Wisdom

The common theme of these pearls is simply that technology may not always be the answer and indeed, may cause other problems or set up obstacles that impede mission performance.

- Technology can work well, but still not contribute to battlefield performance
- Email, phone and chat proliferate workload irrespective of the chain of command
- Increased capability may decrease effectiveness (more technology, information overload)
- Concern that in network-centric warfare, everything depends on the network – What if it doesn't work?
- The importance of bandwidth in Operation Iraqi Freedom
  - Bandwidth was allocated to the higher echelons, primarily for political and strategic Video Tele Conferences (VTCs)
  - Lower echelons didn't use technology; knew bandwidth wasn't available for operational and tactical needs
  - Lower echelons resorted to low tech methods and systems
  - Particularly problematic for ground forces where individual soldiers needed access
  - Failure to appreciate or quantify the cost of misallocating bandwidth to those who didn't need it for operational use
  - Bandwidth is a resource that we must consciously plan and manage

People Pearls of Wisdom

Dr Funk and Col Exner also provided excellent insights about the importance of people in command and control, and their relationship to technology.

- We can no longer expect to "bend" people to technology; rather, we need to study how best to produce creativity at the nexus of people and technology
- The soldier's acceptance of new concepts and systems is essential to success
  - We need to build confidence in new ideas, and provide equipment and training that meets the soldier's needs
  - Needs are not always task related
  - Needs may be cognitive, behavioral or social, such as how information is displayed, how teams operate, how tasks are shared
- People must have trust in their equipment and receive training to use that equipment effectively
- We must recognize the importance of relationships
  - Commanders who come up the career ladder together often form personal friendships
  - When command and control systems fail, such relationships often take over
- Technical solutions cannot replace human judgment

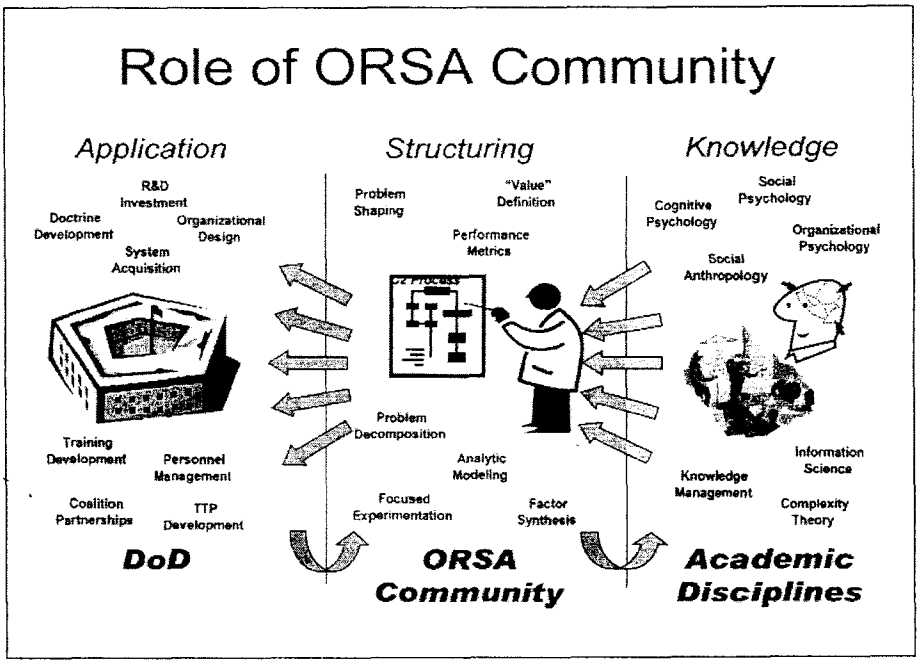

Figure 2

Task Pearls of Wisdom

Col Exner addressed the task element by focusing on decision making tasks. In contrast, Dr Funk considered how tasks might not be performed in a timely manner where the commander requires quantifiable information, more information, or better information. Although both speakers noted the usefulness of qualitative methods, such as observation, interviews and problem structuring, the operations research community has not yet recognized the value of incorporating these types of methods in our analyst's toolkit.

- Decision making
  - How much information is enough to make a decision?
  - The lower the tolerance for risk, the higher the demand for information to avoid that risk
  - Commanders manage information differently, therefore, information must be shaped for the individual commander
- Tasks do not always require quantifiable information
- Just because something cannot be measured or quantified, doesn't mean it isn't important
  - Qualitative methods, such as observation, have their uses as well
- Commanders must perform their tasks in a timely manner
  - Concern that they will wait for more or better information rather than act or make a decision

(See **COMMAND AND CONTROL,** *p. 16)*

(continued from p. 15)

- Need to balance the need for quick decision making with informed decision making

Structure Pearls of Wisdom

Finally, Col Exner addressed how the organization structure may affect performance by examining the role of teams and how their formation in highly centralized organizations can adversely affect mission performance.

- The importance of teams
  - Increased centralization reduces the ability of informal relationships to influence the process
  - Centralization requires the formation of new teams that have no prior history or experience working together
  - Lack of team experience requires rules and procedures that slow the process
  - Slower process does not meet OPTEMPO requirements
- Command and control becomes synched to a sequential, procedural planning mindset rather than the dynamic rhythm of the battlefield

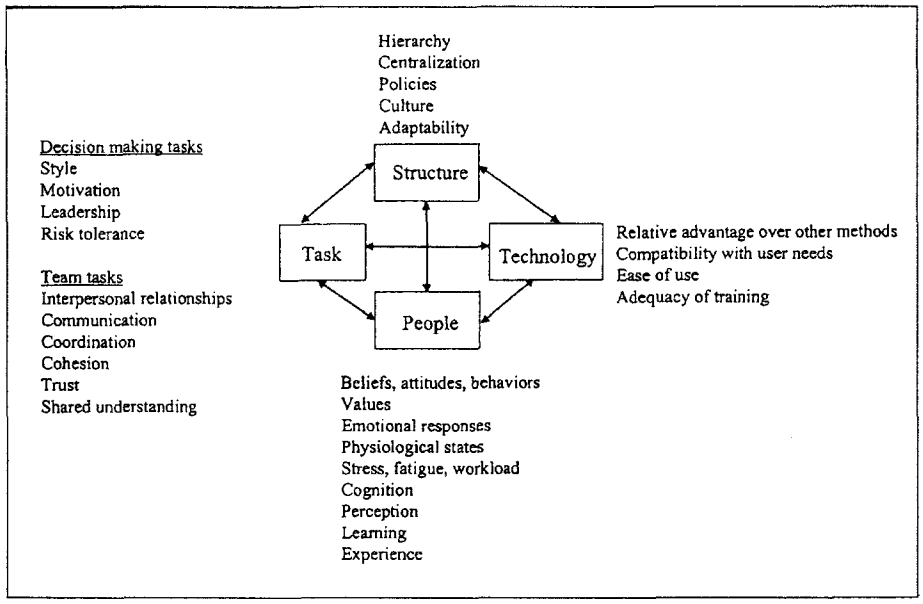

Figure 3.
Cognitive, behavioral and social factors that influence command and control.

Workshop

Objectives

The workshop provided a forum for developing a common ground of understanding among the participants, regarding the influence of cognitive, behavioral and social factors on the design, implementation, and performance of command and control structures, tasks, processes

PROBLEM	C2 Process 1	C2 Process 2	C2 Process 3	C2 Process 4		
	Information Gathering	Decision Making	Communicating	Feedback/Network-Centric Warfare	C2 Technology	C2 Training
Cognitive Factors (Behavior/Aspects)	1) Data overload	1) Groupthink 2) Decision paralysis	1) Bottlenecks 2) Unanalyzed data	1) Real-time filtering	1) Lack of objectives for system development 2) Bandwidth 3) No standards for non-ergonomic cognitive factors for systems design	1) How to recreate a thinking enemy
Human Performance (Behavior; Individual or Team)	1) Fatigue/ physiological stress 2) Signal detection & classification	1) Fatigue/ physiological stress adverse effects are exacerbated 2) Allowing for creativity while adhering to standards	1) Language barriers 2) Cohort issue 3) Service culture	1) Digital systems—alerts/shared knowledge 2) Analog systems—manual processing 3) COA analysis & war gaming	1) Need to accommodate individual differences	1) How to create a physiologically realistic friendly/enemy situation
Command Style (Interpersonal Behavior)	1) Striking the balance of staff autonomy and command-directed necessity 2) Varying levels of micromanagement involved for subordinate action	1) Striking the balance between consistency (standards) of decisions with creativity and initiative 2) Influence of negative command climate	1) Degradation of VTC capability 2) Balance in battle preparation and communications to accommodate robust plan adjustment	1) Identifying causal results attributing cognitive factors 2) Capturing the logic/reasoning involved with actual decisions	1) Automating capture of tagged data to subjective data 2) Design specificity between staff and command requirements	1) How to compensate for absence of experienced commander 2) Training criteria to establish effective command styles 3) Need to represent asymmetric/foreign command styles

Figure 4. Typical problems posed to cognition, behavior, and command style by command and control structures, tasks, processes, and technologies.

IMPLEMENTATION	C2 Process 1	C2 Process 2	C2 Process 3	C2 Process 4		
	Information Gathering	Decision Making	Communicating	Feedback/Network-Centric Warfare	C2 Technology	C2 Training
Cognitive Factors (Behavior/Aspects)	1) Relevance 2) Filters 3) Data aggregation	1) Exercises 2) Trained facilitators 3) Mentors	1) Training in relevant service/coalition language and cultural differences	1) Processes to check for receipt/ misunderstanding critical orders	1) Include cognitive scientists in all phases of acquisition 2) Use of portal technology 3) Visualization technologies	1) Include cognitive scientists in IPTs 2) Develop performance standards
Human Performance (Behavior; Individual or Team)	1) Using staff interactions to determine collection priorities 2) Integrating performance degradation studies with doctrine		1) Consolidate or centralize effort to research/ understand implications of reachback in various types of employment, e.g. UAV, vehicle maintenance, medical consultation, etc.	1) Joint training 2) End of every NCW training exercise should assure HEMP destroys all electronics—continue to fight without NCW	1) Modularity and tailorability solutions 2) Early use of "human in-the-loop" simulation in design and development, e.g. SIL (systems integration labs)	1) Need for training SIL 2) Integrating performance degradation results into simulations/other training models 3) End of every NCW training exercise should assure HEMP destroys all electronics—continue to fight without NCW 4) Training differences between more modular force structure and unit replacement policy
Command Style (Interpersonal Behavior)	1) Experimenting with situational styles to determine guides for particular situations 2) Staff training for different echelons	1) In training focus on creativity aspects of decision-making and capture data relating to environmental factors	1) Experiment with differing command styles during controlled information gaps and battle preparation	1) Allow cognitive scientists to participate in various operations to record selected metrics 2) Gain closer access to commanders' pre-/ post- activities	1) Incorporate technological expertise into decision-making process	1) Ensure in individual, collective sequencing of training, new or alternative technology approaches/capabilities are included 2) C2 training in command style and cultural awareness

Figure 5. Cognitive, behavioral and command style mitigating actions.

and technologies.

Working Group Leaders

The following participants served as co-chairs and recorders of their respective groups:

Working Group 1

Co-Chair: Dr **Alan Zimm**, JHU/APL
Co-Chair: LT **Alex Hoover**, COMOPTEVFOR
Recorder: Mr **Brian Widdowson**, MITRE

Working Group 2

Co-Chair: Dr **Kim Holloman**, EBR
Co-Chair: Mr **Dave Garvey**, Alidade, Inc.
Recorder: Ms **Tina Brown**, MITRE

Working Group 3

Co-Chair: LT **Katie Shobe**, USN, NSMRL
Co-Chair: Dr **Barbara Black**, ARI
Recorder: Mr **Dan McConnell**, MITRE

Working Group 4

Co-Chair: Dr **Lyn Canham**, AFOTEC
Co-Chair: Dr **Gwen Campbell**, NAVAIR
Recorder: 1Lt **Lindsey Schmidt**, USAF, AFOTEC

Synthesis Group

Co-Chair: Dr **Dennis Leedom**, EBR
Co-Chair: Dr **Lynee Murray**, NUWC Newport
Recorder: Ms **Sharon Nichols**, AFSAA

Findings

The following findings draw heavily from the Synthesis Group's outbrief, but also highlight some of the key findings of the individual working groups. Rather than review the working groups' findings in numerical order, they are addressed in logical order following the content of their findings and how each working group's findings fit with those of the other working groups.

WG 1 was responsible for identifying cognitive, behavioral and social factors that influence command and control structures, tasks, processes and technologies. Figure 3 is based largely on that work, although WG 4 also identified many of these same factors as having potentially significant impacts on mission outcomes. Additionally, WG 2 used a similar diagram to reflect the holistic system view that they felt was important in looking toward future needs of command and control.

WG 4 was responsible for identifying methods that can be used to study and measure the influence of cognitive and behavioral factors on command and control structures, tasks, processes and technologies. Following are some of their

(See **COMMAND AND CONTROL,** *p. 18)*

(continued from p. 17)

observations:

- Use a convergence of multiple measures for a single construct
- Shared construct definitions are critical for metric development and measurement success
- Some measurement dimensions:
  - Objective versus Subjective
  - Process versus Outcome
  - Quantitative versus Qualitative

WG 4 also identified some of the gaps that currently exist in our method and measurement capabilities:

- There are fewer methods for studying teams and organizations than for studying individuals
- There is a need for more interdisciplinary collaboration, including that between the physical and social sciences
- Methods and metrics are needed to assess data-poor environments
- Uncertainty exists in determining which factors should be measured to obtain the most relevant insights into a problem

WG 3 examined how knowledge about cognitive, behavioral and social factors might be implemented in command and control structures, tasks, processes and technologies. They developed a detailed spreadsheet (Figure 4) that examined the problems posed to cognition, behavior and command style by such processes as information gathering, decision making, communicating, providing feedback, technology and training.

For example, information gathering can cause data overload at a cognitive level, fatigue and physiological stress at a human behavior level, and invoke problems associated with micromanagement in terms of command style.

WG 3 then developed a second spreadsheet (Figure 5) that examined the implementation of cognitive, behavioral and command style actions to mitigate these problems.

For example, to alleviate the problem of data overload, WG 3 recommended that the relevance of incoming data be assessed to filter or aggregate data and avoid cognitive overload. Similarly, data collection priorities could be established through staff interactions to preclude fatigue and physiological stress. Finally, experimentation with different situational styles could provide alternative responses at the command level to avoid micromanagement.

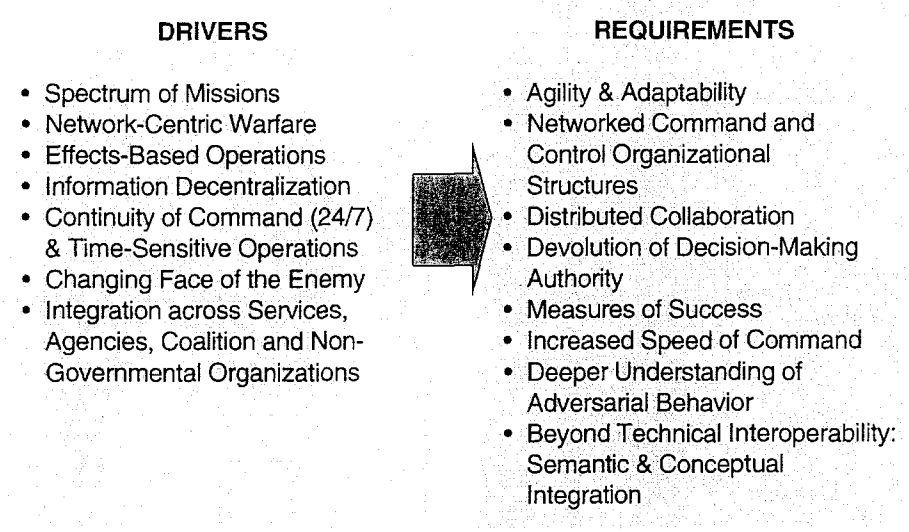

Figure 6. Key drivers and requirements for the future.

WG 3 also explored some of the barriers that hamper knowledge sharing about cognitive, behavioral and social factors.

First, they noted that socio-cultural differences among the Services contribute to significantly different views of command and control, which further lead to different views of cognitive, behavioral and social components of command and control.

Second, WG 3 observed that it is widely accepted in DoD that the future will involve a wide spectrum of military operations, involving coalition partners and large numbers of non-military organizations. It is necessary that any program dealing with the cognitive, behavioral and social components of command and control recognize and incorporate these complexities.

WG 3 also addressed the apparent accepted adequacy of legacy systems. Specifically, DoD has already fielded

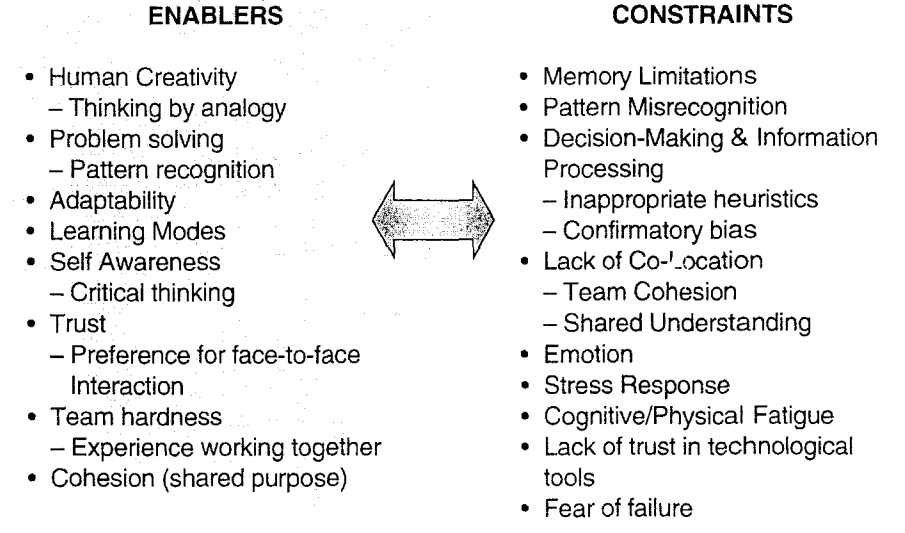

Figure 7. Key cognitive, behavioral and social enablers and constraints

many command and control programs without adequate consideration of cognitive, behavioral and social factors. While there is considerable concern about the lack of recognition of those factors, DoD has otherwise seemed satisfied with its accomplishments to date. The apparent adequacy of present and planned command and control programs will be difficult to argue against. Analyses are needed to demonstrate the benefits of incorporating cognitive, behavioral, and social factors in the design of command and control systems.

Finally, WG 3 noted that introducing cognitive, behavioral, and social factors in the design, development, test, acquisition and deployment of command and control systems is a complex process that will require ingenuity, perseverance, and considerable high-level support in the DoD.

WG 2 was responsible for examining the ramifications of cognitive, behavioral and social factors on future command and control systems. Figure 6 resulted from their deliberations and those of the Synthesis Group in identifying the key drivers and resulting requirements for future command and control systems.

The left hand box shows the set of drivers that suggest the nature of future military operations. In turn, these drivers call for certain cognitive, behavioral and social requirements that are expected to characterize future missions. It is important to think of the requirements in terms of what they mean to the *human* component, rather than in terms of the mission, task or technology. For example, agility and adaptability refers to the human, rather than the command and control process. Similarly, distributed collaboration refers to the people who collaborate, rather than the tools used to collaborate.

The Synthesis Group noted that we must understand, model, measure and develop human enabling factors that are necessary to fulfill the requirements listed in Figure 6. Some key enablers generated by WG 2 are listed on the left-hand side of Figure 7.

However, we must also recognize the inherent constraints that the human brings to the table, some of which are listed in the right hand box of Figure 7. Both enablers and constraints must be accounted for in the conceptualization and design of future command and control structures, tasks, processes and technologies.

Recommendations

The following set of recommendations was derived from the pearls of wisdom provided by the mini-symposium speakers and from the products of the working groups and Synthesis Group. Again, they follow the format illustrated by Leavitt's Diamond.

Technology

- We need to better assess the direct contributions of new technologies on battlefield performance through studies and analyses during system acquisition and initial fielding. Those technologies that adversely affect battlefield performance should be refined or removed.
- We need to conduct information overload studies that examine the impact of multiple, competing media (email, phone, chat, etc.) on individual and team workload and effectiveness. Changes should be made to doctrine and organization structures to employ only those media that have a positive impact on individual and team workload and effectiveness.
- Research is needed to identify network dependencies and to determine the optimal mix of uses for limited bandwidth and other network assets. System or structure redundancies should be available to mitigate potential network failures. Alternative lines of communication and collaboration should be identified in the event that the network fails.

People

- We need to identify the cognitive, behavioral and social needs of individuals and teams, as they relate to command and control structures, tasks, processes and technologies.
- User acceptance studies of new structures, tasks, processes and technologies should be conducted to ensure that new approaches and tools meet the cognitive, behavioral and social needs of the users.
- We need to assess the role of trust in technology, and identify approaches for instilling confidence and trust.
- Training programs must be developed to incorporate the user's cognitive, behavioral and social needs.
- We need to better understand the roles of informal relationships and their influences on command and control decisions and actions.

Tasks

- We need to conduct studies to determine how much information is enough to support decision making. What is the quantity and quality of information that is needed? How reliable do information sources have to be?
- Decision tools must be designed that shape information for the individual commander.
- We need to incorporate qualitative methods in the analyst's toolkit to enhance information gathering and assessment.

Structure

- Finally, we need to more fully examine the role of teams in command and control. How do teams fit within existing organizational structures? How are teams formed? What team roles can be identified? How is team experience and trust developed? How is workload shared within a team? What processes make teams effective? And how do teams use various technologies to their advantage?

Summary

As a result of this special meeting, a broader understanding was achieved concerning the roles that cognitive, behavioral and social factors play in influencing command and control structures, tasks, processes and technologies. The alternative holistic perspective afforded by Leavitt's Diamond as an organizing concept greatly contributed to the coverage of the special meeting topic, despite its breadth and depth. Finally, the commitment to discussion and fair debate among the participants ensured that a balance of views was heard and that shared appreciation was achieved.

It is expressly hoped that this special meeting will serve as the genesis for a series of MORS meetings to address cognitive, behavioral and social factors as they relate to command and control, and more broadly, to the practice of military operations research. Although this special meeting established a starting point for future discussions, there is much work yet to be done. ✪